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CONVERSATIONS

ON

THE ANIMAL ECONOMY:

DESIGNED FOR THE

INSTRUCTION OF YOUTH

AND

THE PERUSAL OF GENERAL READERS.

BY ISAAC RAY, M. D.

In explaining these things, I esteem myself as composing a solemn hymn to the great Architect of our bodily frame, in which, I think, there is more true piety, than in sacrificing hecatombs of oxen, or in burning the most costly perfumes.

Galen.

PORTLAND:

166329.
PUBLISHED BY SHIRLEY AND HIDE.

1829.

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DISTRICT OF MAINE, TO WIT :

DISTRICT CLERK'S OFFICE.

BE IT REMEMBERED, That on the eleventh day of May, A. D. 1829, and in the fifty-third year of the independence of the United States of America, Messrs. Shirley & Hyde, of said District, have deposited in this office the title of a book, the right whereof they claim as proprietors, in the words following, *to wit* :

Conversations on the Animal Economy, designed for the instruction of Youth, and the perusal of general readers. By Isaac Ray, M. D.—In explaining these things, I esteem myself as composing a solemn hymn to the great Architect of our bodily frame, in which, I think, there is more true piety, than in sacrificing hecatombs of oxen, or in burning the most costly perfumes.—*Galen.* Portland, published by Shirley & Hyde, 1829.

In conformity to the act of the Congress of the United States, entitled "An Act for the encouragement of learning, by securing the copies of maps, charts, and books, to the authors and proprietors of such copies, during the times therein mentioned;" and also to an act, entitled "An Act supplementary to An Act entitled An Act for the encouragement of learning, by securing the copies of maps, charts and books, to the authors and proprietors of such copies, during the times therein mentioned; and for extending the benefits thereof to the arts of designing, engraving, and etching historical and other prints."

J. MUSSEY, *Clerk of the District of Maine.*

A true copy as of record,

Attest,

J. MUSSEY, *Clerk D. C. of Maine.*

TO

PARKER CLEAVELAND,

Professor of Mathematics and Natural Philosophy, and
Lecturer on Chemistry and Mineralogy,

IN BOWDOIN COLLEGE,

This humble attempt to aid the cause of education, and
The diffusion of useful knowledge,

Is respectfully inscribed,

As a tribute of

GRATITUDE AND ESTEEM.

ADVERTISEMENT.

The increasing taste for the study of the Natural Sciences, has created the necessity of an elementary work on the most interesting of them all, the science of the Animal Economy, in which every thing of a strictly professional nature, and whatever else would be improper for general readers, should be carefully excluded, and the whole rendered intelligible to the minds of the young and the unlearned. To meet this necessity has been the object of the author in preparing the following sheets. To the merit of originality, he lays no pretensions ; but if the manner in which the subject is here treated, shall prove an inducement to acquire some useful and interesting knowledge concerning the noblest of the works of nature, it is the only merit that he would claim. How far he has succeeded in accomplishing this object, is for instructors and common readers to say.

Portland, May 11, 1829.

Note. Notwithstanding an attentive revision of the press the author regrets that many errors have escaped his notice. The only one, however, which he thinks it necessary to point out, for they are generally such as the reader instantly corrects, is that of *coronoid* process, for *condyloid* process on the 38th page.

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CONVERSATION I.

Anatomy—Physiology—Comparative Anatomy—Life—Distinctions between organic and inorganic bodies—between animal and vegetable beings.—The primitive tissues—cellular, muscular and nervous properties of the tissues—their elementary composition.

Dr. B.—I hope, Emily, you have not forgotten the arrangements that we made for devoting some attention this season to the study of the animal economy.

Emily.—I recollect your kind promise, Dr. B., but I confess I do not anticipate that pleasure from the study of this subject which we derived from that of Chemistry and Natural Philosophy. My notions respecting it are, perhaps, vague and limited, but they are of such a disagreeable and repulsive nature, that it really appears as if I could never become interested in the study.

Dr. B.—You have identified the study of the animal economy with that of anatomy, and associated with it, no doubt, horrid ideas of dead bodies and mangled limbs, and all your early impressions of “raw head and bloody bones.” You are old enough now to dismiss such narrow and childish notions, and regard anatomy as it really is—the science that unfolds to us a knowledge of the noblest and most interesting works of the Creator. To obtain a certain measure of this knowledge, it is not necessary for us to encounter the repulsive scenes of the dissecting-room, or to notice those numberless disagreeable details which are attended to by professional men. It will be sufficient for our purpose, merely to examine

the most interesting results of their researches, without troubling ourselves particularly, with the means and instruments by which they have been obtained.

Emily.—Will you have the kindness to tell me what the nature and objects of anatomy are, for I believe that my ideas of this science are extremely imperfect.

Dr. B.—Every object in Nature is said to be either organized or unorganized, and these two classes of bodies are distinguished from each other by peculiar modes of structure and properties. Every organized body is composed of various parts or organs which are all dependant on one another, and whose mutual action is necessary to keep the whole body in existence. It is the object of anatomy to unfold the intimate structure of these organs, and to ascertain their form, situation and connection with one another. Defined generally, therefore, it is called the science of organization.

Emily.—I think I have seen the expression, comparative anatomy—pray tell me why this epithet is used?

Dr. B.—Anatomy may be considered as of two kinds—human and comparative. The first is the anatomy of man; the latter, of the inferior animals. It is called comparative because its results are constantly compared with those of human anatomy, which is taken as the general standard of comparison. Now, I presume, you can readily understand its utility.

Emily.—Yes—for since anatomy generally is the science of organization, it must evidently be better understood if we extend our views through the whole animal kingdom, instead of confining them to the structure of man alone. While defining terms, tell me what is meant by Physiology, a term that is frequently used in connexion with anatomy?

Dr. B.—Literally, it signifies the science of nature in general; but in the restricted sense in which it is now received, it means the knowledge of the functions, or uses of the various organs which compose an organized body. A more proper term has been lately proposed.

and will probably be ere long generally used—Biology, or the science of life.

Emily.—I have always thought that I had a sufficiently correct idea of *life*, but after the rigid precision with which you have defined your terms, I am afraid that my notions will prove rather indefinite. The terms *vital principle*, *living principle*, &c. have led me to consider life as something altogether distinct, and superadded to the body; in the same manner as the mind is considered to be a principle distinct from, and independent in its existence of the brain.

Dr. B.—Your notions are erroneous, but it is not altogether your fault, since they have prevailed among medical men themselves, who have strangely mistaken an abstract term, for a self-existent and governing principle. This mistake, which arose, no doubt, from a want of precision in medical language, is for this reason unpardonable now. By some of the best physiologists of the present day, the term *life* is used to express the general aggregate or combination of those properties which are peculiar to living beings, and which are also called *living*, or *vital* properties. The only correct definition of *life*, therefore, would be the enumeration of these properties, and we can obtain exact and comprehensive notions of it, only by considering what these properties actually are.

Emily.—Do, Dr. B., explain them, for I am impatient to know what these curious properties are, that are so different from impenetrability, divisibility, attraction, &c. which are common to all matter.

Dr. B.—In the first place then, every organized body is composed of both solids and fluids which are continually in motion—continually acting on each other. This is necessary to the very conception of a living being.

Emily.—But you forget that crystals contain a certain portion of water, which is essential to their existence as crystals.

Dr. B.—But it is water in a solid state—there is no

motion between it and the other parts of the crystal. A second distinction between organized and unorganized bodies consists in this; that the various parts which make up the former are different from one another, while those of the latter are perfectly alike. If we break a granite rock in pieces, we shall have every fragment however small alike, except in form and size—in every one we shall find feldspar, mica and quartz. But if we break in pieces a living body, we have in one portion, skin and muscle; in another, nerves and vessels; in one, bark and wood; in another, leaves and fruit. The parts of an unorganized body, when separated from one another, still present the same properties as the whole mass. If it be a magnet, every part will attract the needle, though with less force, just as the magnet did before it was broken. But the parts of an organized body, when separated, lose the properties which they possess only when combined and acting together. If you tear a piece of flesh from the body, or an eye from the socket, the one will no longer feel, nor the other see.

Emily.—And yet I have heard that there is an animal called the Polypus which may be divided into a number of parts, and every part will immediately become a perfect polypus, resembling the original in all respects except in size. This must certainly be an exception to your principle.

Dr. B.—Before you form your conclusions so hastily, you should assure yourself that the facts are strictly true. If you had taken pains to obtain the true history of these creatures from scientific books, instead of adopting the popular notions, you would have found that they were far from being exceptions to our principle. The plain truth is, that in that class of animals called Zoophytes, which are the simplest of all animals in construction, there are many which may be divided into several parts, and every part will continue to live and grow, and in the course of time will have grown to the form, and

possess all the properties, of the perfect animal. But this requires time, and is produced by a regular process of growth and developement, for immediately after this division is made, the parts are motionless and apparently without life.

Emily.—Are not those sea-anemones which we observed yesterday clinging to the rocks on the beach, animals of this kind? I think you said they belonged to the class of Zoophytes. If they are, I should like to try the experiment on those which brother George brought home. How must they be divided?

Dr. B.—You may divide them into two portions, either horizontally or vertically, and after a time you will find that both pieces have attained the size and form of a perfect animal. But we must postpone these experiments to a leisure hour, for recollect we are digressing from our subject.

Emily.—I think, Dr. B., that I can point out a very prominent distinction between organized and unorganized bodies,—the former in the early periods of their life, are constantly growing in size, while the latter do not grow in the least, but remain the same, year after year.

Dr. B.—True indeed, they do not *grow* in the same sense as organic bodies grow, but you do not suppose, do you, that minerals have never increased in size, but were created by the great Architect just as you see them. Minerals do increase in size by what is called *accretion*; that is, by the accession of new layers of particles to their surface, without any change in their nature; thus they may be augmented to an indefinite extent. All minerals have been formed in this manner, and the process is continually going on, though it may not be apparent to us. Organic bodies, on the contrary, grow by *assimilation*, as it is termed; they receive into their interior various substances, all which, by peculiar powers of their own, are converted into one homogeneous substance, and carried to different parts of the body. The

active roots of the plant absorb the nutritious particles from the soil, which are transmitted to the leaves, and there converted into a peculiar substance which furnishes the secretions and nourishing sap. The animal seizes the heterogeneous materials of nourishment which come within its reach, dissolves and decomposes them—endows them with new properties, and at last renders them fit to become parts of the various organs of which it is itself composed. The particles of which an unorganized body is formed, are never changed to give place to others, but continue with the body as long as it exists. But in organic bodies, the particles after a time lose those peculiar properties with which they were endowed, and then—being no longer fitted to remain as parts of a living being—they are taken away and new ones supply their places.

Emily.—I will venture to suggest another distinction, which I hope may prove more fortunate than any other,—the surfaces of minerals are extremely rough and irregular,—or if regular, as they are in crystals, just as remarkably smooth and even. Now, the surfaces of organic bodies are neither rough nor even, but are more or less rounded throughout—the outline continually waving. Is not this a proper distinction?

Dr. B.—Yes; you are perfectly correct, and it is on this remarkable difference of the outline in these two classes of bodies that the beauty of each depends. That gently rounded and undulating form so beautiful in animals and plants, would be a defect in a crystal—for this pleases us solely by the regularity of its angles and the smoothness of its surfaces.—These two classes of beings are essentially different in the manner of their origin. It is a universal law of nature, that living beings derive their origin from preexisting living beings. Every plant and every animal supposes the existence of other plants and animals, more nearly resembling them than any other objects in nature. All living bodies have begun their existence within other living beings, in a rudimentary state

from which they have gradually advanced, and by powers peculiarly their own, have been wrought into forms of symmetry and beauty. *Life cometh only from life.* Minerals are not produced in this way—they originate merely from the aggregation or coming together of parts, every one of which is as perfectly formed, and enjoys the same properties as the combined mass.

Emily.—Do you really mean, that those minute beings found in vegetable infusions and stagnant waters which can hardly be perceived without the aid of a glass, all came from eggs that have been layed and hatched by parents resembling themselves? I had always thought they were produced by the process of decomposition.

Dr. B.—Then I believe you have always thought wrong. Recollect; these beings are minute only to our imperfect eyes. You observed those on the dust of the fig by the Solar Microscope, and is it reasonable to suppose that such beings—as nicely and wonderfully constructed, so far as we can see, as insects of much larger size, and as uniformly resembling one another in appearance—have been produced, not by parents like themselves, but at hap-hazard from the diversified substances that compose the dust of the fig? On the contrary, it seems much more philosophical to believe that these creatures, as well as a vast many others which were once thought by some to be spontaneously created, originate like all other animals. Lately, however, the microscope has brought to light some facts, which, if well established, will show that the creative energy does not act universally in this way. But we had better reserve our remarks on these discoveries for some other occasion.

Emily.—And the termination of organic beings is as distinctive, I suppose, as their origin. Nothing like death, I believe, happens to minerals.

Dr. B.—Yes; death sooner or later happeneth to every living thing—and this constitutes one of the great laws of organization. Do you not see how death is a necessary consequence of life?

Emily.—Why really, I see no absolute necessity which should prevent a living being from always preserving its freshness and vigor, and living on to an indefinite duration.

Dr. B.—True indeed, if you confine your views to a single being isolated from all the rest of creation, but not when you look at the general economy of nature. The materials suitable for the nourishment of living beings, must at some previous time have formed parts of other living beings, so that the nourishment of one is obtained at the expense of some other, and thus necessarily requires its destruction. Contemplate at a general view, the countless forms of being which crowd the vast domain of Nature. Do you not see the strong continually preying upon the weak, and these in their turn yielding to others still higher in the scale, and so on through the whole series—even from the spider that entangles its victim in its treacherous web, up to man himself, the greatest destroyer of all. Thus it is in Nature, that renovation and decay—destruction and creation—death and life, follow each other in constant and rapid succession, as necessary parts of the great system of the universe.

Emily.—The characters you have mentioned are common to both animals and plants,—are there none which distinguish these two classes of beings from one another?

Dr. B.—There are several which serve as general characteristics, but naturalists have hitherto found it very difficult to find any character which should clearly distinguish them without any exception.

Emily.—It appears as if I could very easily point out a distinction; for surely animals are endowed with the power of voluntary motion, roaming about according as their wants or pleasures prompt them; while plants are immutably fixed to one and the same spot, through their whole period of origin, developement, and death—or if, as is the case in some instances, they float about unat-

tached to any particular spot, it is at the will of the waves, not their own. .

Dr. B.—In a majority of cases, no doubt your distinction will hold good, but a little better acquaintance with Natural History would furnish you with abundant exceptions to it, as a general rule. Do you not recollect those vast beds of muscles which we observed the other day from the beach—and those little shell-fish, called Barnacles, adhering to the piers of the wharfs, and the bottoms of vessels? Not one of these creatures, as well as a multitude of others which might be mentioned, ever move from the spot where they originate.

Emily.—Well, Dr. B., no plant possesses feeling, whereas it is enjoyed by all animal beings.

Dr. B.—You are very unfortunate in the choice of your terms, for you could have scarcely found one that has been used more indefinitely than *feeling*. If you mean by it a consciousness of receiving impressions from without, it is not peculiar to animals,—for the motions of many plants are determined by the impressions of surrounding objects, in the same manner as those of a multitude of Zoophytes. The *Seaanemone* when disturbed, draws in its delicate feelers and retires as much as possible within itself, with no more consciousness of impending danger, than the sensitive plant, which, when rudely touched, instantly closes its leaves. If you place one of those soft, jelly-like beings, called by Naturalists, *Medusae*, and by the sailors sea-nettles, sun-fish, &c.—very abundant in our waters in the summer months,—into a vessel of water, and the light be permitted to fall only on one side of the vessel, it will constantly turn in that direction. So too if a plant be placed in a darkened room in which a few rays are admitted by a single aperture, its branches will imperceptibly move towards it. Some plants close their flowers at the approach of rain; these medusae close themselves up from the same cause. Thus you see that in this sense, feeling is no more an universal characteristic of animals than voluntary motion.

Emily.—Then of course you will not admit that vegetables have a consciousness of their existence,—and yet how can we reconcile it with the goodness of the Creator, to suppose that he has created such a profusion of life as the vegetable world possesses, without bestowing upon it capacities for a greater or less degree of happiness. At any rate, it is a beautiful theory, this—that the woods and the fields are filled with sentient beings that are animated, not merely by the life that supports their existence, but by a nobler spirit, capable of consciousness and delight.

Dr. B.—So long as you admire the picture for its poetry, not for its truth, your admiration is not misplaced. The presumption of an acquaintance with the designs of the Deity, which this theory assumes, is a sufficient objection, if there were no other to its correctness. When we take a survey of the scale of being, we see the capacities of enjoyment continually diminishing, until they are entirely lost in the mineral world. Now, it is no more inconsistent with the goodness of the Deity to have denied capacities of happiness to vegetables, than to have varied them in animals, and entirely annihilated them in the mineral kingdom. Besides, the power of perceiving pleasure and pain, consequently requires that of voluntary motion, in order that its possessor may obtain the one and avoid the other. Since voluntary motion has been denied to vegetables, we must believe that sensation has been withheld likewise—unless we would impeach that very benevolence which is adduced in favor of the theory. The power of perceiving the good and the evil, with an inability of pursuing the one and avoiding the other, has been imparted by nature to none of her objects. Fanciful poets indeed, in order to excite our sympathy for helpless suffering, have represented the trees of the forest as animated by sentient beings whose tears issue through the wounds they receive.

A distinction that has been strongly insisted on is—

that in animals the nutriment, before undergoing any essential change is first received into a general cavity in their interior, from which it is absorbed and carried to the various parts of the body, while in plants the nutritious particles are carried along through a multitude of minute vessels which never open into a single general cavity. Many of those animalculæ which are produced in vegetable infusions are thought, however, to imbibe their nourishment from every point of their external surface. If this be the case, they are of course exceptions to the general rule. The corallines too, which absorb their food from the waters by their numerous feelers acting like the roots of plants, must in strictness be considered as exceptions. Perhaps the best distinction that has yet been offered, is that of Mirbel, founded on the kind of nourishment adapted for their support. We know that plants alone have the power of obtaining nourishment to a considerable degree from inorganic matter, such as salts, earths, airs,—substances that are certainly incapable of serving as food for any animals, since they invariably feed on organic matter either of a vegetable or animal nature. So that it would seem to be the office of vegetable life alone to transform inorganic matter into organized living bodies.

Emily.—I think I could furnish an objection to that distinction without much difficulty : The earth-worm has nothing but earth to eat ; and the leech, I have been told, will live many months on nothing but water.

Dr. B.—Most earths and water, contain in a greater or less degree particles of organic matter ; and it is these which furnish the principal nourishment of these creatures.

You must now exercise all your faith till I have time fully to explain the wonderful truth which I am now going to communicate to you—all the diversified organs of the body, no matter how different in density, color, strength, or function, are every one composed by the various combinations and modifications of a very few sin-

gle organic parts, called the primitive *textures* or *tissues*. They are commonly reduced to three—the *cellular*, the *muscular*, and the *nervous*.

Emily.—And do you mean that the skin, hair, nails, bones, tendons, nerves and vessels, are all formed out of these simple tissues alone? It is inconceivable to me how substances so different can be composed of precisely the same constituent parts. However, I will mind your caution and wait with patience for a solution of the mystery.

Dr. B.—Your haste prevented me from adding that the solid parts of the body only were composed by these tissues, and that the solid parts of the body bear a proportion to the fluids no greater than 1 to 6—some say 1 to 10. The solids also are not always composed of animal substances; for in some of them we find a portion of earthly matter which has been deposited by the fluids.

The simplest in structure, the most abundant in quantity, and the most extensively diffused, is the cellular tissue. It enters into the composition of every organ in the body. In a very condensed state it forms the main bulk of the bones, tendons, ligaments, nails, hair; in a softer and looser state, we find it in the skin and the internal organs; in the form of a thin membranous expansion, it serves as coats for the vessels and sheaths for the muscular fibres. It fills up the interstices between the muscles and other parts which lie near together, and gives to the whole surface of the body that beautiful rounded outline which we were so much admiring. If every other portion of the body could be removed and the cellular tissue left undisturbed nearly the same form and size of the body would remain. It is therefore justly considered as the basis or framework on which all other parts of the body are built.

Emily.—But why is it called cellular texture; has this term reference to its mode of structure, meaning that it appears in the form of cells?

Dr. B.—Yes, for when closely examined by a microscope after the necessary preparation, we observe whitish threads or fibres of extreme delicacy—much finer than the finest cobweb—which, intersecting one another in all directions, leave minute spaces which are termed cells, and may be very aptly compared to those of the honey-comb. These cells all communicate with one another, so that from a single spot, the whole body may be distended with air or water. This is the reason why the hands and feet of dropsical people are more inclined to be distended with water than other parts—the water gravitating to the lowest level it can find. This intimate communication is still more remarkable in regard to air, for sometimes when an accidental opening has been made from the air-cells of the lungs into the contiguous cellular tissue, the air has penetrated into every portion of it, and the whole body become puffed to such a degree as almost to occasion suffocation. Butchers are said, to sometimes give their meat the appearance of fullness and rotundity, by blowing air into the cellular tissue.

Emily.—What are its properties, Dr. B.? I suppose that entering so largely as it does into the composition of the body, it must be endowed with numerous and important properties.

Dr. B.—So far however is this from being the case, that out of its four properties, not one is of a vital nature, but are all common to it and inorganic matter. They are cohesion, flexibility, extensibility and elasticity. This last property is peculiar to the cellular tissue; and its operation in some of the most important actions of life, are such as to elicit our admiration at the striking contrast between the simplicity of the means and the beauty and magnitude of the result. In all cases where accommodation to variations of capacity, pressure, &c. is necessary, there we find the cellular tissue—beautifully calculated under some one of its numerous modifications, to answer any of these diversified objects. After

this description, perhaps you may be able to recognise it in a quarter of beef or a shoulder of mutton.

Emily.—I presume it is that delicate, white expanded substance which we see in various portions of its surface ; and when I pull asunder the fibres of the red parts of the meat, it appears in the form of very minute and hardly perceptible threads, passing between the fibres and connecting them together.

Dr. B.—Yes ; and these red parts which constitute the chief portion of meat, are formed by the second, or *muscular* tissue. These fibres, if you will take the trouble to trace them out, will be found to be of considerable length, and arranged parallel to one another. A mass of these fibres completely enclosed and separated from the rest, in a sheath of cellular tissue, constitute what is called a muscle.

Emily.—I do not observe this sheath which you speak of—it must have been removed from these muscles.

Dr. B.—You may not see it, perhaps, since it is so exceedingly thin and closely applied ; but it really is present. If you move your finger carefully over it, you will find it smooth and slippery—very different from the sensation produced by the irregular surface of the naked muscular fibres. The fibres themselves are found to be composed of fibres still smaller ; and if our powers of vision were sufficiently great, we might find these to be made of others more minute, and so on till we come to the ultimate fibre—that which is susceptible of no farther division.

Emily.—But does the muscular tissue always exist, as it does here, in the form of long, thick masses ?

Dr. B.—No ; these constitute but a portion of all this tissue which may be found in the body. It sometimes appears in a *membranous* form ; that is, in thin, broad expansions ; in a tubular form, it serves for one of the coats of all the blood-vessels, and is found answering the same purpose in the gullet, stomach and other cavities that require occasional distension.

Emily.—What a bright and beautiful red these muscles present ; pray what is the cause of this brilliant hue ?

Dr. B.—It is probably owing to a portion of blood still remaining in their vessels, or effused between their fibres. Whatever it may be, it does not seem essential, for by maceration in hot water or alcohol, they may be deprived of it without altering their texture in the least. The muscles of fishes are perfectly white, and so are some of those in man which are not in the form of large, fleshy masses.

Emily.—Are the properties of the muscular tissue as simple and common as those of the cellular ? It is so different in appearance, that I am expecting to find that its properties are very different from, if not more complex, than those of the latter.

Dr. B.—Your conclusion is correct. Muscle, as it exists in the body in connexion with the cellular tissue possesses both physical and vital properties. The first of these it owes to the cellular tissue, and of course are the same as those we have already described ; but its peculiar and specific property, is strictly of a vital nature. It is called *contractility*. By virtue of this property the muscular tissue possesses the power of shortening itself on the application of various kinds of stimulants. Let a fibre be exposed and pricked with a needle or wet with a drop of aqua-fortis, and you will see its two extremities approaching each other by retracting, and the middle becoming swollen and hard. This property of contractility is the source of immense power ; it is by muscular contraction that the various movements of the body are effected, as well as some of the most important actions of life.

Emily.—To tell the truth, Dr. B., I do not see very clearly how it differs from elasticity. The fibre it appears, yields to the force which is applied, and returns to its original condition when that cause is removed.—Is there any thing more in this than what we witness in elasticity ?

Dr. B.—You must bear in mind that in elasticity there is never a real generation of power—the effect produced is never greater than the cause which sets it in action. In the recoil of a steel spring there might at first sight, appear to be an actual generation of power ; but it is a well-known fact that the force with which the spring recoils is precisely equal to that which is used in compressing it. And so in every piece of machinery, the power produced is never greater than that which has been expended. But in muscular contraction there is a real generation of power, for the force with which a muscle contracts, bears no proportion to that by which it is excited. If you prick the internal surface of the heart in an animal recently killed, it will contract with so much force as to almost bury up the needle in its substance. See too, what violent agitation you may produce in the muscles of a frog, simply by irritating them with a pin. Are you not convinced now, Emily, that contractility is altogether different from any other property of matter ?

Emily.—Partially perhaps, but I am still in doubt how the fibre returns to its original condition, unless it is by its elasticity.

Dr. B.—*This* is probably produced by elasticity, but this does not take away the necessity of some different property to explain its contraction.

Emily.—But simple contractility merely shows the fact that the power of shortening itself is inherent in the muscular tissue ; it does not explain by what means this effect is produced.

Dr. B.—So many theories have been published with this object in view, and all so feebly supported by facts, that it would be hardly worth your while to be made acquainted with them. Those which have any advocates now, make contraction to depend on electricity, or galvanism, or some change in the chemical combinations of the elements of the muscle. We cannot stop to discuss these theories—suffice it to say that in the hands

of their several advocates they are all plausibly supported. It is a singular fact in reference to contractility, that though it is generally very strongly excited by the electric fluid after death, yet it is entirely lost in a body that has been killed by lightning—in an animal that has been run to death, or that has died from the operation of poisons. It has also been observed that the rapidity with which putrefaction takes place after death is inversely in proportion to the powers of contraction which remain in the muscles. But we must now hasten to the *nervous* tissue.

Emily.—It is this, I presume, which composes the nerves, those curious organs that are so much concerned in the operations of the mind. I promise myself much gratification from your account of this tissue.

Dr. B.—It not only composes the nerves, but the brain, spinal marrow and other important parts. It has a soft, whitish, and pulpy appearance, but when properly prepared it is observed to possess a fibrous structure—its fibres being arranged parallel to one another, as in the muscular tissue. To the nervous tissue belongs the general property of sensibility, or the power of transmitting impressions that are made on it, from one part to another. This, however, is manifested in such different ways that there appear to be distinct kinds of this power. Thus, a wound in the head may be followed by sickness of the stomach; in which case, an impression is communicated from one of these parts to the other without the knowledge of the mind. This kind of sensibility is the most common and the most essential to life. By its influence, the various parts and organs of the body are enabled to communicate together, and thus a beautiful harmony is maintained through all their complicated actions. Secondly; an external object touches the body and an impression is carried immediately to the mind by which it is made acquainted with the fact. This is an instance of a second kind of sensibility and is popularly termed sensation, but is more accurately distin-

guished by the term *perceptibility*. Thirdly; the mind conceives the wish of grasping that object, and an impression is forthwith transmitted to the hand which moves in obedience to this wish. This illustrates a third kind of sensibility, which in common language is termed *volition*.

Emily.—I thought that volition was strictly a property of the mind—an intellectual operation, whereas, you consider it if I understand aright, a property of the organic tissue.

Dr. B.—Volition no doubt, originates in the mind—there is its fountain-head, but since we cannot conceive of its taking place without the action of the nervous tissue, it is more convenient to regard the whole act as dependent on that tissue, leaving at rest the primary cause by which it is produced.

Before we close this account of the primitive tissues, we shall have time just to notice very briefly their ultimate structure. The microscopical discoveries that have been lately made in reference to the primitive structure of the simple tissues are highly interesting, since they throw new light on the nature of organization in general. All the simple tissues when examined by a powerful microscope, after being properly prepared, are found to consist of an aggregate of minute filaments each of which is formed by a regular series of globules. These globules whether observed in the cellular, muscular or nervous tissue, do not sensibly differ from each other in aspect or dimensions. They are alike, also, in all species of animals, from man even to the Zoophyte. The only difference seems to be in the direction of the filaments, which in the cellular tissue intersect each other in apparently a confused manner. In the muscular tissue the filaments instead of being bent from their line of direction, and running into each other are arranged in parallel rows, separate and distinct from one another. In the nervous tissue the globules form lines less zig-zag in their direction than those of the cellular, but deviating

from the parallelism of the muscular tissue; not so straight as the one nor so convoluted as the other. Observers differ in respect to the size of these globules; some say they are one four thousandeth, others, one six thousandeth, and others still, one eight thousandeth part of an inch in diameter. But what renders these observations peculiarly interesting is the discovery—made partially, indeed many years ago, but recently confirmed by many new and curious facts—that if vegetable or animal substances be macerated for some time in water at a moderately warm temperature, the fluid will be found, after a certain time, swarming with animated bodies too small to be within the reach of unassisted sight. They have been styled Infusoria because they have been generally observed in vegetable infusions. The simplest form of these creatures is that of a transparent globule, so small that it appears to be a mere animated point. They have the same form and magnitude as the elementary globules of which the primitive tissues are composed.

Emily.—But how is it known, Dr. B., that they do really possess life?

Dr. B.—That fact is inferred by their rapid and unceasing motions which have every appearance of being spontaneous.

Emily.—And yet it is so clear that these motions may not be occasioned by heat, electricity, or some other physical cause?

Dr. B.—We cannot say but they are—yet so long as the agency of no physical cause with which we are acquainted can be demonstrated to be present, we have no right to affirm its existence, if the fact of their vitality be strengthened by considerable evidence. For microscopical observations have made us acquainted with other minute beings differing from these simple globules only by a slight addition to their structure. In one kind this difference consists in the addition of an appendage in the shape of a tail. Next above these in the scale of complexity, is another kind which seem to consist of

globules enveloped in a common membrane without any opening. Then this form varies by tapering at one extremity into a kind of tail or neck. Next we see them endowed with external organs, consisting of hairs or bristles. Again instead of a cavity without an opening as is the case in all that we have yet described, we find at one extremity a distinct aperture, thus forming the first rudiment of an alimentary canal. Next we meet with processes or lashes around the opening for the purpose of propelling the fluid by their motion into the alimentary cavity. Thus we may go on tracing these minute forms of organization through their increasing complexity until at last we come by these small gradations, to beings endowed with a special digestive organ and special organs of motion.

Emily.—We are to conclude then, I suppose, that the elementary globules which compose the primitive tissues are living bodies capable, when separated from each other of spontaneous motions—and that it is upon this one simple organic point, that every form of organic matter is built up from the Infusoria even to man himself. In truth, this is a most interesting and curious fact.

Dr. B.—Such a conclusion would, no doubt be just, were the accuracy of these observations beyond a question. But since other naturalists have been unable to verify them and hence have doubted the accuracy of their results, we are thereby not warranted in adopting this general principle.

Having now described the primitive tissues, our next step will be to consider the several organs which they form, and the functions which their organs accomplish.

Emily.—If they are numerous, I never shall remember much about them without the aid of some classification. May we not divide the body into head, trunk and limbs, and these again into smaller divisions ; then we should greatly facilitate the study of them.

Dr. B.—The various organs are already classed,

though not according to their relative situation, but according to the functions which they perform. The superiority of this method of arrangement you will distinctly see, before we have finished our studies. We find several organs associated together for the purpose of effecting one general result which is termed their function, and they are designated by the name given to that function. Thus, those engaged in the process of digestion, are called the digestive organs; those engaged in respiration, respiratory organs, &c. Again, we see that the general tendency of all these functions is two fold—the nutrition and growth of the body simply, and the connexion of the being with the world around it, by which it receives a higher and nobler existence. This forms two general divisions of the organs of the body; the first being called the organic functions, or functions of organic life; the last the animal functions, or functions of animal life. In our next conversation we shall take up the organic functions commencing with that of digestion.

CONVERSATION II.

Digestion—possessed by vegetables as well as animals—alimentary canal—its coats—the teeth—mastication—lateral motion of the jaws—deglutition—descent of the food into the stomach—abdomen—stomach.

Dr. B.—The function of digestion is that by which the various articles of aliment are received into the interior of the animal, converted into one homogeneous mass, deprived of some qualities and endowed with new ones, and finally fitted to be carried into the system and submitted to the operation of other processes which prepare it for its destined purposes. It is the most essential function in the whole animal economy, and seems to be the ground work of all the others.

Emily.—According to your definition then, the function of digestion is possessed by vegetables. It is a whimsical idea indeed, to conceive of digestion without a stomach or a mouth, though to be sure, this method has one redeeming quality,—its possessor is never in fear of dyspepsia or toothache.

Dr. B.—It is immaterial what names we use, provided we distinctly understand their meaning, but since the process by which the sap is absorbed in the roots, and carried to the leaves where it is converted into a particular juice of an entirely different nature, which supplies the plant with the materials of growth and secretion, will come under the definition that we have given of digestion, this term is rightly applied to it. Besides,

some of the Infusoria are as destitute of stomach and mouth as vegetables. But before we speak particularly of the digestive function, we will take a slight glance at the various organs that are engaged in performing it.

Emily.—Pray, Dr. B., how many organs do you reckon? I had no idea of any other than the stomach, and I cannot conceive why this is not sufficient.

Dr. B.—It is because you take a partial view of the function. Though the most important part of it is performed in the stomach, yet there are several auxiliary processes to be accomplished without which our food would be but poorly digested. Before it is taken into the stomach it must be torn in pieces and chewed by the teeth and mixed with the fluids of the mouth. Then it requires to be conveyed to the stomach—which is accomplished by the act of swallowing, the result of a delicate contrivance in the mouth. After it has passed through the stomach another cavity is prepared in which it is mixed with the bile and other juices, and a system of vessels to take it up and carry it into the blood.

Emily.—I was not aware till now of its being such a complicated process, though I hope this will not induce you to abbreviate your account from the fear of being tedious; I am sure I never shall lose my interest in your instructions.

Dr. B.—It will not be necessary here, as well as in other parts of the science to be very minute, for there are many discussions and details which it would be useless for us to meddle with. We therefore, shall look only to the most important and generally received views. The digestive cavity, or alimentary canal as it is most commonly called, is a long tube with a high degree of vitality, provided with the necessary apparatus for secreting the various fluids to be used in the digestive process, varying in form, length and calibre according to the habits of the species. This tube lies convoluted upon itself, and is of very unequal capacity in its different parts—being capacious in the mouth, contracted in the gullet, which again expands into the stomach, and

then suddenly contracted, it continues onward with various degrees of capacity. In man, its length is five or six times that of the whole body. In the inferior animals, we find it larger, longer, and more complicated in those whose food is entirely of a vegetable nature, than in those which are supported by an animal nourishment exclusively.

Emily.—Is not this because food which has just formed part of an animal body requires less preparation to fit it for nutrition, than that which is of a vegetable nature?

Dr. B.—Your explanation is probably correct. The walls of the alimentary canal, differ in its different parts, in appearance and capacity, and are found throughout their whole extent, to be formed by two membranous coats, which though they do not together amount to the thickness of one eighth of an inch, are exceedingly strong, and by their toughness and elasticity are capable of resisting a great degree of force. The inner of these coats or that with which the food comes into contact, is called the mucous coat. Its appearance is different in different parts of the alimentary canal, being thin and smooth in the mouth which it completely lines, thicker and more loosely applied in the stomach, and collected into transverse wrinkles, or folds in the intestines. It is formed by cellular tissue and provided with numerous minute glands from which a fluid is poured out to keep it constantly moist. The next coat is called the muscular, and is formed by muscular fibres running in two different directions, one layer being longitudinal, the other, circular. The third coat called the serous or peritoneal and external to these two, is found only in some portions of the alimentary canal.

Emily.—I am afraid I shall obtain but a poor idea of these parts that form the alimentary tube without some plate or model.

Dr. B.—And yet, I suspect, you have seen more than once, what is better than either plates or models—the object itself.

Emily.—Why surely Dr. B., you cannot be serious ; I never in my life beheld a stomach, nor any part of one.

Dr. B.—Perhaps not a human stomach. But tripe, an article of food, which no doubt you have seen and eaten in the course of your life, is the stomach of the ox, which, in the same way as man's, has these three coats which I have described. After it has been fried you can easily separate them and see their relative connexions.

Emily.—I recollect now distinctly the soft and delicate appearance of the mucous coat and directly under it, the muscular coat with its red and parallel fibres very perceptible.

Dr. B.—As different parts in the process of digestion are performed in different parts of the digestive system of organs, it will be convenient for us to describe them both in connexion, proceeding in the order in which they present themselves.

Emily.—And first I suppose, we have the mouth with its appendages. Pray do be particular in describing the teeth, for you know, I have particular cause to be interested in their organs.

Dr. B.—Well then let us look at the mouth in the first place. In shape, it approaches the oval nearer than any other figure. Above it is bounded by an arch formed by a bone called the *palate* ; below by the tongue ; behind chiefly by the *veil* of the *palate* and the *pharynx* ; anteriorly by the lips, and laterally by the cheeks. This cavity may be greatly enlarged, you know, by separating the jaws, and the cheeks, and depressing the tongue. The upper jaw constitutes a portion of the face and therefore moves only with the head ; the lower jaw on the contrary, is fixed by joints to the head, and is capable of considerable extent of motion—moving freely upwards and downwards, and a little from side to side. To understand the admirable though simple contrivance by which this lateral motion is effected, cast

your eyes on the branch of the jaw which you see in this figure below, (see p. 40,) and observe how it terminates in a convex knob of an oblong shape, called by anatomists the *coronoid* process. These processes are inserted into corresponding cavities in the head, just under the ears. The cavities being a little longer than the processes, these latter move freely from side to side. In the jaw of a cat however, we find that the cavity is no longer than the process, and of course all lateral motion is prevented.

Emily.—But why is this Dr. B? Some end, no doubt, is answered by this peculiar conformation of the jaw.

Dr. B.—Man does not possess it exclusively, but has it in common with many of the inferior animals. If you will listen with patience till you have learnt a little more of the other parts of the mouth, I trust you will be able to explain the cause of this difference without my assistance. As for their structure the teeth differ from all other bones in superior hardness, and in having the surface of the upper portion protected by a thin layer of a substance the hardest of all others in the body. By means of the *enamel* as this is called, the teeth are effectually preserved from the influence of the atmosphere and the chemical action of the various secretions of the mouth. When the latter are heedlessly suffered to accumulate on the teeth, the enamel is sooner or later destroyed (for the time depends on the acrimony of the secretions which vary according to the state of the constitution,) and as it is never renewed, the parts beneath are invaded and the whole tooth begins to decay.

Emily.—A forcible hint for us, certainly, to cultivate assiduously the friendship of brushes and dentifrices, if we would avoid the attentions of the dentist.

Dr. B.—The portion of the tooth below the gums is called the roots or fangs; that above being styled the crown of the tooth. The enamel covers only the crown, for the roots are sufficiently protected by the surrounding

parts in which they lie completely and firmly imbedded.



Within each root there exists a canal leading up into the crown where they all terminate in a common cavity, as you may see in this figure, in which they are represented by the black space. In these canals are enclosed the nerves and blood vessels which serve for the nourishment of the tooth.

Emily.—It is when this cavity is exposed by disease, I presume, that we experience that distressing affliction, the tooth ache, which too often obliges us to resort to the soothing properties of cold iron. Could not the pain be prevented, and the tooth preserved by destroying the nerve in some way or other, as I have sometimes heard proposed?

Dr. B.—And supposing you could succeed in the operation of destroying the nerve, what would it avail you in the end? Do you imagine that the nerve is placed there for no other purpose than to give pain, and that the tooth can do perfectly well without it?

Emily.—I see my mistake now, but I never before saw the subject in that light. The tooth then requires its proper nerves as well as other parts, without which it tends to decay and death.

Dr. B.—The teeth, you observe, differ considerably in their form and size. In the front of the mouth you see four in each jaw, rather flat and terminating in a sharp edge. These are called the *incisors* or cutting teeth, and are the first to make their appearance in the young child. Behind these in both jaws and on each side you may observe one distinguished from the incisors by superior length and by terminating in a point. They are called canine or dog teeth, from the circumstance of their being very conspicuous in the dog when he raises his lips under the influence of anger. The other teeth are much larger, their faces are terminated by a few blunt points, and the roots are two or three and sometimes four in number. They are called *molars* or

grinding teeth, and when all are cut amount to twenty, making the whole number of the teeth thirty two. The last tooth in each jaw is not cut till about the twentieth year, and is called the *wisdom* tooth. The teeth are now firmly fixed in the jaw in cells or sockets formed by thin plates of bone rising up from the jaw, as you may see in the figure below. The only use of these sockets is to



contain the teeth, and when they are no longer wanted in consequence of the loss of the teeth, they are absorbed.

Emily.—Is not this the cause of that approximation of the chin and nose so striking in old people who have lost their teeth? It would seem that the sockets of both jaws being taken away the distance between these two parts of the face must be considerably diminished.

Dr. B.—Yes; your explanation is correct. We are now prepared to consider the action of the mouth on the food, or what physiologists call the process of *mastication*. The food taken into the mouth is in the first place conveyed back and forth between the teeth by the tongue, the incisors cutting it in pieces, and the molares grinding or breaking it down. This action of the molares is particularly necessary when the food consists of grains or hard fruits, and you see now how much this grinding process is facilitated by the lateral motion of the jaws.

Emily.—And I suppose the reason why the cat does not possess this lateral motion of the jaws, is that its

food being raw flesh, in its wild state, it rather required to be cut or torn in pieces than ground, and the upward and downward motion of the jaws is sufficient for this purpose.

Dr. B.—This is the case, not only with the cat, but with all carnivorous or flesh eating animals; their molares also uniformly terminate in sharp points, and their incisors are long and pointed. In herbivorous or vegetable eating animals, on the contrary, the molar teeth are much larger and their faces present a rough and irregular surface, the better to fit them for grinding hard grains and tough herbage.

Emily.—Horses, oxen and some other animals ought to have, I should think, teeth with the power and hardness of mill-stones, to break down such hard, tough substances as corn, hay and many other articles which they feed upon.

Dr. B.—Their teeth are admirably calculated for this purpose. They are very large, and are not only surrounded by enamel, but vertical plates of this substance are found in the interior of the tooth, interposed with its earthy parts, and rising to the surface of the tooth. This prevents the tooth from wearing away as it inevitably would, if the enamel were not present.

Emily.—I recollect now having observed, when I have been looking at the teeth of a horse or ox, several undulating, zig-zag lines on their surface. This is caused I suppose, by the earthy substance being worn away, and leaving the harder plates of enamel projecting above them. But is this the manner in which the teeth are always prevented from wearing away when subject to considerable use?

Dr. B.—It is in a great many animals, but in the *gnawing* animals, such as the beaver, rat, squirrel, &c. there is a very different contrivance. To be enabled to cut through such hard solid bodies as they do with perfect ease, they are furnished with two strong incisive teeth in the front of each jaw. The enamel is found

only on the anterior surface of the tooth, so that the posterior surface being soon worn down, the tooth has a bevelled edge. But without some contrivance or other, this thin edge though composed of enamel would yield, and the tooth be at last worn down to the gums. To obviate these inconveniences, the teeth are furnished each with a very long root which grows upward and supplies the waste of the crown. In some of these animals they have a prodigious length, extending backwards nearly to the angle of the jaws.

Emily.—Those animals have no canine teeth, and neither, if I am not mistaken, have the horse and ox ; at least there is a space in their jaws where the canine should be, and it is here that the bit is received in the former animal.

Dr. B.—You are right ; and not only are the canine sometimes wanting, but also the molares. In the dolphins of various kinds, the teeth which amount frequently to two hundred in number, are all canine. In Fishes too, they are all canine. You have seen many times these terrible instruments in the jaw bones of sharks, where the points are extremely sharp, and the edges serrated. And to render them still more efficacious, they have the power of raising or depressing them at will. You want no one to teach you that their food must be exclusively flesh.

Emily.—So then by a simple inspection of the teeth you believe we may ascertain whether an animal lives on flesh, or a vegetable diet.

Dr. B.—Yes ; and where it subsists on a mixed diet we can tell with some certainty the proportion of each.

Emily.—If that be the case then, why may we not settle the long agitated question, whether man was destined by nature to live on an exclusively animal or vegetable diet, or on a mixed diet of both.

Dr. B.—It cannot be determined from the form of the teeth only, for the reason that nearly all the food of man except ripe fruits, undergoes the preparation of

cooking, by which it is so softened, that very little necessity exists of much grinding or cutting powers in the teeth. During mastication, fluids are constantly poured into the mouth from various glands in the cheeks under the tongue, and in fact from every part of the mucous membrane. By the *saliva* as these fluids are called, the food is moistened, and its comminution more easily effected—and perhaps, a little changed in its chemical properties. Being now prepared for the action of the stomach, let us follow its course, and examine the means by which it is conveyed to that organ. This process is called *deglutition* or swallowing, and although apparently a very simple thing, a distinguished physiologist pronounces it, “by far the most complicated of all the muscular actions which assist in digestion.” To understand it fully, let us look first at the parts which are concerned in producing it. Attached to the middle of the posterior edge of the palate, you may observe by looking into your own mouth by a mirror, a soft, loose body formed by folds of the mucous membrane, called the *veil of the palate*, which by means of eight little muscles that are inserted into it, may be moved in a great variety of directions.

Emily.—I observe it distinctly—but what are those bodies, one on each side of it, resembling it in color and apparently in texture?

Dr. B.—Those are the *tonsils*, commonly called almonds—a collection of mucous glands. Passing on between these, we arrive next at a sort of vestibule or chamber, called the *pharynx*. In this vestibule we find several apertures leading in different directions, viz. two to the nostrils, called the *nasal fossæ*; one on each side to the drum of the ear, called *Eustachian tubes*; one to the wind-pipe, called the *chink of the glottis*, which is furnished with a sort of valve, called the epiglottis, capable when shut down, of completely closing the chink. Several muscles are attached to the pharynx, which give to it a great variety of motion. Behind, and attached to

the pharynx, is the *œsophagus* or gullet, a cylindrical tube lying near the back-bone in the chest, and terminating in the stomach. Now, when a morsel of food is ready to be swallowed, it is placed on the superior surface of the tongue which is then closely applied to the arch of the palate. The muscles strongly contracting on the food, it is necessarily directed backward, this being the only direction in which it can escape from the surrounding pressure. Having now reached the pharynx, contrivances are obviously required to prevent it from falling into any of those apertures which open into that cavity, except the right one. The veil of the palate, therefore, being drawn back by its muscles, is applied like a valve over the aperture leading to the nasal fossæ and Eustachian tubes, and thus the morsel is effectually prevented from passing into either of them.

Emily.—It does pass through, sometimes, notwithstanding all these obstacles, for it happened to myself this morning while eating my breakfast, filling my eyes with tears, though but the instant before I was heartily laughing.

Dr. B.—And for this very reason was it, for when we are coughing or laughing, and swallowing at the same time, the air rushing up from the lungs through the chink of the glottis, pushes the food along towards the nasal fossæ with considerable force.

Emily.—It is prevented from entering the wind-pipe, I suppose, by the epiglottis shutting down, and permitting the food to pass safely over it, as upon a bridge. How admirably this object is effected by this beautiful contrivance!

Dr. B.—Withhold your admiration a moment, till you are certain that the cause of it actually exists. Your explanation was the one generally given, until it was proved a few years ago, by Majendie, the distinguished French physiologist, to be inadequate for the purpose. That the epiglottis shuts down as you have imagined, is undoubtedly true: but Majendie cut off the

epiglottis in several dogs, and found that the creatures swallowed just as well as before—showing that the effect in question is produced by some other means. He then divided the nerves which supply the muscles of the larynx, by which they were completely paralysed, and found that deglutition became very difficult, the food falling into the glottis and choking the animal. Hence it followed, that in the act of swallowing, the muscles of the glottis were put into action, thus closing the aperture and preventing the food from passing into the wind-pipe.

Emily.—A very satisfactory result, no doubt—but was it not very barbarous to subject so many innocent creatures to such painful experiments? I am sure, if physiology has been always cultivated with such frightful means, my pleasure in its study will be greatly diminished.

Dr. B.—Recollect that we are constantly exercising that power over the brute creation which nature has put into our hands, and so long as it is done for good purposes, it is undoubtedly well and right. A whole species, in many instances, is condemned to incessant hard labor on our account, and others are raised for no other purpose than to be killed at last for our food. In comparison then with all this amount of suffering, of which nobody complains, what are a few experiments, painful though they may be, the object of which is to enlarge the boundaries of human knowledge. It must be the very essence of maudlin sympathy and short-sighted views, that would stigmatize such experiments as useless and disgraceful to human nature.

Emily.—I confess, Dr. B., I never thought of it in this light. I am convinced now, that these experiments are amply justified by their utility in advancing the interests of scientific knowledge. But, pray go on with your account of deglutition—I believe, we left the food in the pharynx, having got safely clear of Scylla and Charybdis, and ready for its downward route into the stomach.

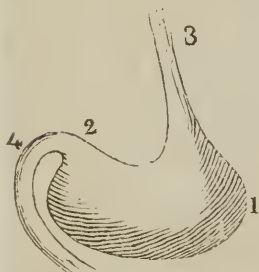
Dr. B.—The pharynx now contracts and pushes the

food into the gullet. The circular fibres of this organ, stimulated by its presence, contract upon it and thrust it onward. The next set of fibres, then act and propel the food still farther, until by means of this successive contraction of the circular fibres, it at last reaches the stomach. Deglutition seems at first thought to be perfectly under our control, yet nearly all its acts are entirely beyond it, and are purely instinctive. The food must be of just such size and quality, and properly masticated, before it can be swallowed, endeavor as much as you will to get it down. Try to swallow your saliva five or six times in quick succession, and you will see how impossible it is to perform deglutition by the will, unassisted by any instinctive wants. You know how difficult some people find it to swallow a pill.

Emily.—I believe I can testify to the truth of that fact myself, and, I am confident, you would be the last person to refuse my testimony.

Dr. B.—The rest of the digestive operations take place in the *abdomen*, the largest cavity in the body, and containing, besides the stomach, many other important organs. This cavity is irregularly egg-shaped, and

bounded on the upper side by the diaphragm or midriff, a thin membranous muscle, disposed in the form of an arch over the top of the cavity, and separating it from the chest. Posteriorly the abdomen is bounded by the back-bone, and anteriorly and laterally by the abdominal muscles, the action of which is likewise considerably connected with that of the organs within. In the upper portion of this cavity, on the left side, is situated the



1. Cardiac portion of the stomach.
2. Pyloric portion of the stomach.
3. Oesophagus.
4. Commencement of the intestinal canal.

stomach, a figure of which you may see in this engraving. It is likened by some to a Scottish bag-pipe in

shape, but may be more accurately considered as a conoid bent upon itself. Into its left and largest portion, the oesophagus enters, and this is called the cardiac orifice. From the extremity of the opposite portion, we see the origin of the intestinal canal; the opening by which this communicates with the stomach, is called the pyloric orifice. The relation of the stomach to the surrounding parts varies according as it is distended with food, but it is not worth our while to notice all these changes of position. Its external or peritoneal coat is reflected upon it from the walls of the abdomen, but its edges, instead of uniting together where they meet on the opposite side, are prolonged down some distance before they unite, forming what is called the *omentum*, or caul. Being liberally furnished with fat and cellular tissue, it lies down over the stomach like a curtain, and gives to this organ additional warmth and security. The stomach is abundantly supplied with nerves and blood-vessels, receiving four great arteries, three of which are exclusively appropriated to itself. So important is this organ to the living economy, and so extensive and numerous are its sympathies with all the others, that disease or derangement in almost any part of the system, generally disturbs sooner or later—sometimes immediately—the natural harmony of its functions. A single blow directly over the region where it is situated, has been known to produce death with the rapidity of lightning.

Emily.—Now, I hope you are ready to relate the changes which the food undergoes in this wonderful organ. Pray, what prevents it, if the pyloric orifice remains open, from passing directly down into the intestinal canal? A valve, or some other contrivance, I should think was necessary, in order to keep it closed while the food is digesting.

Dr. B.—Do not be impatient; you shall understand it all in due season. But, for the present, we must let the subject rest till our next conversation.

CONVERSATION III.

Chymification—the gastric juice—artificial digestion—digestion in Birds—digestion of liquids—influence of digestion on the other functions—effect of exercise on digestion—influence of the mind on digestion—drinks—natural diet—chylification—bile—liver—pancreas—spleen—lacteals—rumination—digestion of Reptiles and Fishes, of Mollusca and Zoophytes.

Dr. B.—At last the food has reached the the stomach, and the second stage of the digestive process begins. Stimulated by the presence of the food the muscular fibres around the two orifices contract and close them up, and fluids poured out in great abundance and mixed with the mass of food. In this state it remains without any perceptible alteration, for a space of time which varies exceedingly under different circumstances, though when the digestion is healthy and the food simple, it may be stated at about an hour. After this time, a change commences in that portion in the pyloric part of the stomach lying in contact with the mucous coat by which it loses most of its original properties, and is converted into a soft homogeneous substance of a very different nature, called chyme. This substance has a greyish appearance, is of a pulpy consistence, has a sweetish as well as slightly sour taste, and changes vegetable infusions to a red. A general description however, can hardly be given, since it varies in some degree accor-

ding to the nature of the aliments, for in fact there seems to be as "many species of chyme as there are varieties of food." The chyme when formed is moved towards the pyloric orifice into which it enters, and new portions are brought into contact with the stomach, until the whole has undergone this change.

Emily.—But can't you say a little more definitely, how this marvellous phenomenon has been produced. I hope it is not wholly involved in obscurity—if the curiosity of physiologists has been so strong as mine, I am sure they have not left its extrication unattempted.

Dr. B.—If you could see but a moiety of the discussions and speculations which this subject has occasioned, you would be convinced that for once at least, men had proved themselves in respect to that praise-worthy spirit of curiosity, not unworthy of being mentioned in connexion with your own sex. The older physiologists were utterly ignorant of the true nature of chymification, although they made divers theories to explain it. Some of them imagined it to be a sort of concoction or stewing of the food, and this continued to be a very common opinion till the revival of learning in modern Europe. The chemical philosophers who had their day in the beginning of the last century, banished this theory forever, and promulgated the more fashionable one, by which this process was considered to be neither more nor less than a true fermentation. In a short time this doctrine was eclipsed by that of the mechanical philosophers, who regarded chymification as nothing more than mere trituration or grinding, the food being ground up by the walls of the stomach which were thought to be endowed with immense power. One of the supporters of the trituration theory even calculated the force with which the coats of the stomach acted in digestion, which he gravely estimated at 12,900 lbs. The celebrated Dr. Hunter in his laconic way, has humorously exposed the absurdities of these theories, while he has pointed out their common source of error. "Gentle-

men," said he to his class one day, "some phisiologists will have it, that the stomach is a mill; others, that it is a fermenting vat; others again, that it is a stew-pan: but in my view of the matter, Gentlemen, it is neither a mill, a fermenting vat, nor a stew-pan; but—a stomach, Gentlemen, a stomach." While endeavoring to explain it on chemical and mechanical principles, they seemed to have forgotten altogether, that it is eminently a vital process—produced by the action of vital laws. The first insight into the true nature of digestion, was obtained by the illustrious Reaumur. He attributed it to the agency of a peculiar fluid found in the stomach, being a secretion from that organ, which is styled the gastric juice, and though he over estimated its singular properties, yet his notions in the main are correct and have been confirmed rather than discredited by time. Some of the experiments that have been made to test the powers of the gastric juice are exceedingly conclusive. Thus, a man who was in the custom of swallowing divers heavy and indigestible articles for his own amusement, was made to swallow at different times, hollow metallic balls perforated with holes and filled with meats of various kinds. These balls being examined after a certain time, their contents were invariably found reduced to perfect chyme. If the gastric juice be the sole agent in digestion, it must be the most powerful solvent in nature, not only dissolving the hardest substances, as bones and various grains, but materially changing their chemical properties.

Emily.—I am extremely curious to know the chemical composition of this juice; if it corresponds to the importance and singularity of its effects, we might expect to find in it some new substance in nature.

Dr. B.—It has been frequently analyzed, but I believe no substance has been detected in it not before known. It is not the same in different animals, nor always so in the same individuals, but varies according to the species and the nature of the food. It is difficult too,

to obtain it unmixed with the other secretions. These are the causes of the conflicting results which experiments made to ascertain the composition of the gastric juice, have generally presented. Later experimenters, by whom these circumstances have been kept in view, have found it composed chiefly of *water, mucus, alkaline sulphates (chiefly soda,) hydrochlorates, phosphates, muriate of lime*, and a few other salts in minute proportions. The acidity is occasioned by the presence of *hydrochloric* and *acetic acid*.

The gastric juice is not only a powerful solvent, but has remarkable *coagulating* and *anti-putrescent* powers. Dr. Fordyce states that five or six grains of the mucous coat of the stomach—from which it is no doubt secreted—infused in water, gave a liquor which coagulated more than a hundred ounces of milk. We find that milk when taken into the stomach is invariably coagulated before digestion can take place. Of its antiputrescent qualities there is abundant proof. The fact has been frequently verified by experiments, that putrid meat by being introduced into the stomach of animals, will after a short time become perfectly sweet. It has been ascertained that the gastric juice of the dog and crow will preserve veal and mutton thirty days; whereas the same meat kept immersed in water will give out a fœtid smell as soon as the seventh day, and become perfectly offensive on the thirtieth.

Emily.—I should think that the digestive powers of the gastric juice might be satisfactorily tested by obtaining it from the stomach of some animal, and immersing different articles of food into it. I should be delighted to witness its effects. Cannot we try the experiment?

Dr. B.—We may spare ourselves that trouble, for your idea has been anticipated long ago, by many physiologists.

Emily.—And with what success did they meet?

Dr. B.—It could not be rationally expected that out of the body, beyond the influence of the vital powers,

the gastric juice should produce the same effects as in the stomach. The most that could have been expected is only an approximation to the process of digestion, and so far late experimenters have fully succeeded. Various kinds of meat, bread, milk, &c. which have been exposed to the action of the gastric juice of the dog, duck, and other animals, have been uniformly observed to be broken down, and the outer portions at least changed into a pulpy greyish substance, resembling in appearance true chyme. Some very interesting experiments on the digestive powers of the gastric juice in man, were published a short time since in an *Edinburg Medical Journal*, which were performed by a surgeon in the American army. The subject of the experiments was a young Canadian, who, in consequence of a wound in the stomach occasioned by a musket shot, had an external communication with that organ, though at this time his health was excellent and his appetite good. By taking off the pad which he wore over the opening, he could easily remove the aliment and his medical attendant frequently introduced into his stomach various sorts of meat tied to a string, for the purpose of observing the changes produced by digestion. In one of these experiments, an ounce of clear gastric juice was drawn off by means of a gum-elastic syphon into a phial capable of holding three ounces. This was about 11 o'clock A. M. and the mercury in the tube of a thermometer introduced into the stomach, stood at 100° of Fah. A small piece of boiled beef was immediately immersed in the fluid. The bottle was well corked and placed in a temperature of 100°. In about 40 minutes the digestion had evidently commenced on the surface of the meat. At 50 minutes, the fluid in the phial became opaque and cloudy. The fibres of the meat began to be disengaged, and in one hour chyme seemed to be forming. At P. M. the muscular fibres had diminished one half. At 5 o'clock, very few remained—and at 7, there was scarcely any visible trace of muscle. At 9, the whole

substance was completely dissolved. The solution had now the appearance of whey, and shortly afterwards a precipitate resembling the meat in colour fell to the bottom of the phial. It was now well corked up and showed no appearance of change, till thirty one days afterwards, when it exhaled a putrid odour.

On the same day, and at the same hour a piece of meat of exactly the same size and kind as that placed in the phial, was introduced into the stomach, with a thread attached to it. At the end of one hour, it presented nearly the same appearance as the piece in the bottle. At one o'clock, the thread came away, the meat appearing to be entirely dissolved. The process in each case was the same for the first hour; but afterwards the meat was more quickly digested in the stomach than in the phial. In both cases, the digestion commenced at the surface of the meat, and seemed stationary there for a certain time. In the phial, gentle agitation seemed to quicken the solution, by presenting new points of contact for the gastric juice.

Emily.—Since then the gastric juice will exhibit its peculiar powers in some degree, out of the body, and we are acquainted with its chemical composition, why may we not prepare an artificial gastric juice that would produce similar effects?

Dr. B.—It is probable that this fluid possesses vital as well as chemical properties; whereas one made artificially by combining its constituents, would be destitute of these vital properties. We know perfectly well the composition of the blood, but all the chemists in the world could never make true blood by combining its constituent elements. However, experiments of this kind have been tried, but they are not yet complete. The German experimenters have ascertained that diluted acetic acid, diluted hydrochloric acid, a weak solution of acetate of ammonia, and a solution of hydrochlorate of ammonia, severally dissolve more or less of animal sub-

stances that are used as food ; but they have not yet tried their effects in conjunction.

Emily.—The gastric juice of the ostrich, I should think, possess the solvent powers of aqua fortis ; for I recollect reading an account of one which was brought a few years ago to New York, which on one occasion, swallowed a pocket handkerchief, and afterwards swallowed daily, gravel, bits of china ware, glass, nails and other metallic substances which he picked up in the yard where he was confined. Its health continued good during the first eight days after swallowing the handkerchief, but it soon lost its appetite and died.

Dr. B.—In truth, these were truncheon feats, which modern gourmands, resolute as they are, might blush to hear ; unless we except a hardy son of Neptune you may have heard of five or six years ago, who was accustomed to swallow jackknives for his shipmates' amusement.

Emily.—This account stated, that on examining the ostrich after death, its stomach was found quite full, and distended by a quantity of partly digested grass, mixed with corn and potatoes in a like state, and a great quantity of gravel, glass, brass buttons, old nails, and a piece of a small key. All which appeared to have undergone a strong friction, as if they had been rubbed or polished with a file.

Dr. B.—This extraordinary digestion is to be attributed, not solely to the gastric juice, but also to a triturating power of the coats of the stomach possessed by all birds that live on grains and other hard fruits. The stomach is composed of strong fleshy masses of muscle, and possesses two distinct cavities. The first has the form of an irregular oval, with strong, hard muscular walls, which when in action exert an astonishing degree of power. The internal surface has the hardness of horn itself. Physiologists have been fond of comparing this organ to a mill, the upper part resembling the hopper, or receptacle for the grain, and the two projecting oval sur-

faces, the mill-stones,—the intestine receiving the grain in its divided state. It is a mill too, which acts with no ordinary power, as you have seen in the case of the ostrich. Spallanzani, the Italian physiologist, whose bold and ingenious experiments often astonish while they convince the reader, has published on this subject some very curious and interesting facts. He found that balls of glass, and other brittle substances, when swallowed by some of our domestic fowls, were speedily reduced to powder. Tubes of tin-plate were also found to be crushed and broken down. Several leaden balls, each furnished with twelve sharp needles, the points of which projected one fourth of an inch beyond the surface, were introduced into the stomach of a turkey and common fowl. At the end of a day and a half, the animals being opened, the needles were observed to be broken off close to the surface of the ball. In another experiment, he forced down the throat of a turkey, a leaden ball armed with twelve sharp lancets. The creature betrayed no uneasiness, and being opened eight hours after, the lancets were gone, leaving nothing but the naked ball which presented some marks of impressions. The coats of the stomach in all these cases were perfectly unhurt.

Emily.—Our common fowls seem to manifest a striking fondness for such indigestible materials, for I have frequently seen them swallow pebbles, and it is a common notion that they do not thrive when prevented from obtaining them.

Dr. B.—In these animals, they are undoubtedly essential to healthy digestion. The quantity that is sometimes found in them is truly astonishing. Two hundred have been found in a turkey-hen, and a thousand have been taken from the stomach of a single goose. But we must return to the food which we left changed into chyme.

Emily.—You have not yet told what change liquids undergo when introduced into the stomach. The gas-

tric juice, among its wonderful qualities, cannot certainly have the power of converting pure water, which we sometimes drink by tumblers-full, into real chyme. In short, I do not see but that it must pass through the stomach entirely unchanged by that organ.

Dr. B.—Such was the common opinion, till lately, it has been proved beyond all doubt that, generally, liquids find their way into the system by some other route. A ligature has been placed around the part of the stomach just above the pyloric orifice, and still liquids have disappeared as rapidly as ever. Substances have been found in the blood, too soon after being swallowed, to have reached this fluid by the same passage as that taken by the food. When fluids, containing nutritive matter, are introduced into the stomach, they are either coagulated, as in the case of milk, or the liquid parts are absorbed, and the solids converted into chyme, as in the case of broths, gruel, &c.

Emily.—A difficulty has just occurred to me in regard to the solvent powers of the gastric juice, which to me seems wholly inexplicable. If what you have stated be true, I cannot possibly conceive how the stomach itself should escape its power, for its dissolution appears to be inevitable.

Dr. B.—Your objection is specious, and has given rise to considerable unbelief in regard to our theory of digestion. But the physiologists answer it by saying, that the stomach is beyond the influence of the gastric juice in consequence of its own vitality—when this is lost by the death of the individual, it is acted upon like our ordinary aliment. Several cases have been observed of persons who died suddenly while digestion was going on and the gastric juice of course secreted abundantly, where the coats of the stomach, having thus lost their vitality, were found dissolved or corroded in a number of places. It has also been ascertained by experiments that when rabbits were killed soon after eating a quantity

of food, the stomach was found to be dissolved in a similar way.

Emily.—What effects has the process of digestion on the other functions of the body? From considering its importance, and the extensive relations of the stomach with other organs, it might be expected, I think, to be felt in other parts of the system. One thing is certainly produced—the feeling of a gratified appetite gives to the mind a delicious sensation of tranquillity and self satisfaction.

Dr. B.—The vital powers during digestion are said to be concentrated on the stomach, and hence that sense of lassitude and drowsiness which a full dinner frequently occasions. A short nap at such times, is to many people peculiarly refreshing, and undoubtedly facilitates digestion. There is always more or less reluctance to commence active exertion immediately after a full meal.

Emily.—Yet, *Dr. B.*, a little exercise after a meal is popularly considered as conducive to health. At least that has been my belief.

Dr. B.—Physicians have generally eschewed all exercise directly after eating, chiefly on the strength of an experiment performed by Sir Busick Harwood. Two pointers were fed on an equal quantity of the same food—one was suffered to go to his kennel, and lie down, while the other was taken out to hunt. At the end of two hours they were both killed and examined; when in the first the food was found very well digested, while in the other it was scarcely altered. This experiment however proves merely, that violent not moderate exercise, is unfavorable to healthy digestion.

But the truth of the matter is that the effects of exercise after digestion, depend greatly on habit and constitution. To sedentary people and others who have the command of their time, exercise after dinner is exceedingly disagreeable, though after breakfast or supper they can immediately go about their business with alacrity

and vigour. The laboring man on the contrary, no sooner swallows his meals, than he resumes his routine of toil without souring his temper or deranging his digestion. All this difference is the result of habit. In general therefore, we may conclude that a short period of rest immediately after eating is favorable to digestion, while various degrees of exercise may be rendered compatible with good health by habit and temperance.

Emily.—If this then be the case, eating a substantial meal just before going to bed at night, cannot be a reprehensible practice, as it is commonly considered ; since the conditions most favorable to good digestion are present.

Dr. B.—The popular opinion is, notwithstanding, generally correct. The habit of filling the stomach before going to rest is injurious because food is not needed, and the appetite which is felt is as artificial and as morbid, as that which craves tobacco or ardent liquors. Why, the very idea that men whose employments are of a sedentary nature—for such are the ones with whom this practice of eating second suppers is most common—need a substantial meal four or five hours after eating their supper, is truly ridiculous. This appetite, instead of being created by active exercise and temperate abstinence, is solely the result of a long continued habit, and very different from that produced by the ordinary demands of labour. But when food is craved by an appetite created by hard exercise and temperate abstinence, it will never disturb the sleep nor derange the functions. The industrious farmer after finishing the weary business of the day, takes his evening repast and retires immediately to his rest ;—but whose sleep is more refreshing ? whose filled with more pleasant dreams ?

Emily.—The function of digestion is also influenced, if I am not deceived, by the state of the mind. I have known persons who, when their attention has been entirely engrossed by some other object, have forgotten

altogether their dinner hour. I know well enough myself, that a keen appetite may be instantly dissipated by the receipt of unpleasant news, or any accident that occasions fear or anxiety.

Dr. B.—Healthy digestion always requires a cheerfulness of disposition and a serenity of the passions. When anxiety is clouding the mind, or some secret passion preying upon its happiness, the appetite soon fails, food becomes loathsome, a morbid irritability of the stomach ensues, and the blanched cheek and wasted muscle proclaim the origin and effects of the disease.

Emily.—I need scarcely ask, I suppose, whether the usual drinks taken with our food are the best adapted to promote the digestive process. As they are all artificial and more or less stimulating, you would say they are more injurious than beneficial.

Dr. B.—We can have no very strong objections to any but those which contain a portion of alcohol. They sharpen the appetite no doubt, but it is none but a jaded and artificial appetite that needs such stimulus. Pure well-water in consequence of the salts which it holds in solution is perhaps better suited than any other fluid, to dissolve the aliments, and afford a healthy stimulus to the digestive organs.

Emily.—The refinements of modern cookery then are liable to the same objections, for they are in the highest degree artificial and stimulating.

Dr. B.—Some cookery is always required, before our food is capable of being eaten. But beyond this, cookery is useful, only as it renders palatable and agreeable what would otherwise be entirely rejected, and it is therefore conducive to economy. Perhaps nearly as much food is absolutely wasted every day in some parts of our country, as is consumed, for want of a proper knowledge of the art of cookery.

Emily.—And yet notwithstanding all this diversity of food, is not the nutritious portion—that which is alone suited to the nourishment of the body very nearly the

same in all? It is an old saying that "there are many kinds of aliment, while there is at the same time but one aliment."

Dr. B.—It is not strictly true that the nutritious portions of all our food are precisely alike, or capable of being reduced to one common principle, though no doubt it is true to a certain extent. Whether a person lives exclusively on vegetable or animal food, the composition of the body remains the same. Such also is the case with other animals. The flesh of the sheep, which lives entirely on vegetables, and that of the lion whose only food is raw flesh, will be found on chemical analysis to be composed of the same materials.

Emily.—But the effects on their moral and physical dispositions are by no means the same, for in one it is feebleness and timidity; in the other, unrelenting ferocity and powerful strength.

Dr. B.—The diet of an animal, and his moral and physical disposition are far from standing together in the relation of cause and effect. The fierceness and strength of the lion, are inherent qualities of his nature—component parts of his constitution. His digestive system is capable of acting only on animal food, and therefore strength and fierceness were absolutely necessary to enable him to obtain the proper means of subsistence.

Emily.—Still, is it not the case with man, that an animal diet has a tendency to make him strong, fierce and courageous, and a vegetable diet on the other hand to make him weak and timid?

Dr. B.—No doubt you have learnt this notion, as you have many others equally correct, from sources which you supposed were entitled to confidence; but facts are strangely against you. The Negroes in Africa, and the South Sea islanders subsist chiefly on a vegetable nourishment, yet they are remarkable for physical strength, and are not deficient in courage. The Esquimaux and other Polar nations, eat hardly any thing but the flesh of the seal and walrus, and drink their blood

warm from its vessels ; but this diet, instead of assimilating their nature to that of carnivorous animals, produces a degraded condition both of body and mind.

Emily.—Do you believe, then, that a vegetable diet is most natural to man?

Dr. B.—No : I mention these facts, merely to show how erroneous was the notion which you had adopted. All circumstances considered, a mixed diet is probably that which is capable of giving the most perfect development to man's moral and physical powers. But that nature has prescribed any particular diet for the human species generally, is a doctrine but feebly supported by facts. Man, unlike other animals, is not confined to a limited district, and obliged to subsist on whatever he may find within it, but has extended his dominion to the uttermost parts of the earth. Nature, no doubt, meant that he should, for she has given him the power of accommodating himself to the circumstances around him—to the productions, as well as the climate of his abode. In the polar regions an animal diet is absolutely necessary, not more from the impracticability of obtaining any other, than the peculiar condition of the system where all the vital powers seem to have centred in the internal organs, and heat, strong food, and every other stimulus are imperiously demanded to support them against the influence of external agents.

Emily.—Nor does the demand seem to be made in vain ; behold the following delicate bill of fare reported in Capt. Lion's amusing journal, every particle of which was consumed by a young Esquimaux. Solids, 10 lbs. 4 oz.—Water, 1 gallon, 1 pint.—Soup, 1 1-4 pint.—Raw spirit, 3 1-2 glasses.—Grog, strong, one tumbler ! This in twenty-one hours, eight of which were passed in sleep !

Dr. B.—In warm countries, where febrile excitement is the result of any kind of stimulus, vegetable food is most conducive to the health and vigour of the

system, and there it is that the richest treasures of the vegetable kingdom are spread out in the most generous profusion. The slaves in our southern plantations whose diet consists entirely of Indian corn, continue in much better condition and are capable of performing a greater amount of labour, than those whose masters allow them a quantity of animal food, and who on the contrary are weak, drooping and sickly. We will now follow up the changes which the food undergoes in its passage into the system.

Emily.—Having been fully converted into chyme, I presume it passes on into the intestinal canal. I cannot imagine what else can happen to it before it is prepared for the purposes of nutrition.

Dr. B.—Now commences the second stage of digestion, or that of *chylification*, which is produced chiefly by means of the various fluids that are poured out and mixed with the food. Our next step then will be to examine the qualities of these fluids and the organs by which they are secreted. The most important of them is the bile, a slightly viscid, bitter, and yellowish fluid of a very compound nature, being at once watery, albuminous, oily, alkaline and saline. The liver by which it is secreted, is the largest viscus in the whole body. It is situated on the right side in the upper part of the abdomen, and is fixed firmly in its place by several strong ligaments which attach it to the diaphragm. Its surface is concave on one side and irregularly convex on the other, and is divided into several lobes by deep fissures. What renders the construction of the liver peculiarly remarkable is, that while like other organs it has its proper arteries and veins, it has unlike any of them another and a complex system of veins. It is called the *vena portæ*; the proper vessels of the liver are called *hepatic artery* and *hepatic veins*. The *vena portæ* is formed after the following manner:—all the veins which carry back the blood from the intestinal canal, stomach, spleen

&c. at last unite into one large vein and ascend towards the liver. Having entered this it divides into a multitude of minute veins that are sent to every part of it, and the extremities of which are said to communicate with the extremities of the hepatic artery and veins. What the object of this singular arrangement can be, is not yet satisfactorily determined. By some it is thought that the blood brought to the liver by the vena portæ is that from which the bile is secreted, and that the use of the hepatic artery is only to nourish the organ. Others believe that the hepatic artery furnishes not only the materials of its own nourishment, but those for the secretion of bile,—that the vena portæ abounds with the products of digestion which have been absorbed from the intestinal canal, and are subjected to the action of the liver in order that the useless portions may be separated from them and the rest receive a higher degree of animalization. Neither of these opinions is supported by direct proof, though the latter is rendered quite plausible by numerous analogies.

The bile, as fast as it is formed, is transmitted drop by drop by its proper duct into the intestinal canal. This duct communicates with a small membranous sac, called the *gall-bladder*, which contains a quantity of bile a little changed in its properties, being of a greenish colour, less watery, and more bitter and acrimonious. It is generally considered as a reservoir for the bile, when digestion is not going on, and its presence consequently not wanted. This view of its use however, is not universally received, but as the subject is yet very obscure, it would be time unprofitably spent to detain you with any farther speculations. Whatever may be its use, we may be confident that it is not *essential* to the animal economy, for in many quadrupeds, the deer for instance, it is found wanting.

Emily.—Are physiologists any better acquainted with the use of the bile, than they are with the manner in which

it is produced? It certainly seems to be destined for some important purpose, from the complicated system of means used for its production, and its being mixed with the chyme immediately after it has left the stomach.

Dr. B.—That it is not merely an excrementitious or refuse fluid, but is eminently serviceable in digestion in some way or other, is now pretty generally admitted. But as to the precise part which it accomplishes in the process, we are rather in the dark. Some have thought that it acts merely as a healthy stimulus to the digestive organs; others, that it produces those chemical changes on the chyme by which it is converted into chyle. In support of this latter notion some experiments are advanced in which the gall duct was tied, so that the bile was prevented from flowing into the intestinal canal, and the effect upon digestion which was about to commence, carefully observed. In all these cases, the chyme was perfectly well formed in the stomach, but the second stage of digestion, or the conversion of chyme into chyle, was instantly prevented—as no chyle was found in the intestinal canal, but a semi-fluid substance very nearly resembling chyme.

Emily.—But is the bile the only agent of chylicification? I thought you mentioned that there were several fluids poured into the intestinal canal to assist in performing this process.

Dr. B.—There is one other special fluid yet to be mentioned, which is secreted by an organ called the *pancreas*. It is situated in the back and upper part of the abdomen behind the stomach, and resembles in structure the salivary glands in the mouth. The fluid which it secretes, likewise resembles the saliva and is transmitted to the intestinal canal by its proper duct which enters it with the duct of the liver. What its exact use is, is not known; though there can be no doubt that it is highly necessary in the process of chylicification, since

extreme emaciation always accompanies a disease of this organ.

The mucous membrane secretes a peculiar fluid which undoubtedly bears some part in the process of digestion. Haller called it the *intestinal juice*, and thought that eight pounds of it were secreted in the course of twenty four hours. It has not been carefully analyzed, and we are rather ignorant of its properties.

It may be well to mention here the *spleen*, which, though it is generally classed with the digestive organs, has at one time or another, been imagined to have a share in almost every function of the body. Some of the theories which have been made to explain the use of the spleen, are truly rather calculated to excite a smile than invite a serious examination. One old physiologist having observed it uncommonly large in persons addicted to immoderate laughter, forthwith concluded that the spleen was the seat of that propensity; others on the contrary, were confident that it was the seat of that moral affection whose name it bears. Some have supposed that it acted as a sort of wastegate, to receive the superfluous blood of the stomach when not required by that organ; while others have thought it was the liver for which it served this purpose. One thought its office was to form the red globules of the blood, and another, as if to give it an extent of influence proportioned to the trouble and vexation which it had occasioned to inquisitive physiologists, declared that its sole use was to secrete the wax in the ear. Another, after a deliberate examination of the subject, came to the sagacious conclusion, that it had no particular use at all, but an empty space being left after the formation of the other organs, this was put in to keep every thing snug and tight. Its use, whatever it may be, does not seem to be *essential to life*. It has been removed from dogs, without any particular inconvenience, and in one instance it was taken from a man in consequence of a wound, who recovered and did very well.

Emily.—What are the qualities of the fluid which it secretes? I should imagine that this might give some insight into its use.

Dr. B.—If the spleen *does* secrete any particular fluid, it is not carried away by any secretory duct. It seems probable, from the latest experiments, that it is connected with some other function than digestion.

On being mixed with the bile and pancreatic juice, the chyme acquires a more yellowish colour, its taste is more bitter, and its sharp odour is essentially diminished. Soon we find it distinguishable into two portions, one a whitish, milky substance swimming on the surface, which is called chyle, and the other, the greatest in quantity, a yellow pulp. The latter consists of those portions of the aliment that are incapable of assimilation, and are destined to be removed from the system; the former has received a certain degree of animalization, and is now ready for the other changes that are to prepare it for nutrition.

Emily.—Truly, we have a strange and wonderful machinery within us, that can thus work such a metamorphosis in the meat and bread that we eat.

Dr. B.—And the complete metamorphosis is not yet accomplished; many more changes still are to be wrought upon it, before the materials of our food are properly fitted for becoming component parts of the living being.

Emily.—I had forgotten that the chyle was yet to be disposed of; but I cannot possibly conceive what becomes of it. That it must be carried out of the intestinal canal is very obvious, because, being destined to replenish the natural losses of the system, it would be useless for it to remain there.

Dr. B.—Certainly it would, and therefore we find an admirable provision for transmitting the chyle as soon as it is formed, from the intestinal canal into the blood vessels. If an animal be examined in the course of an

hour or two after eating, we shall observe a great number of extremely small vessels arising by imperceptible orifices from the surface of the mucous membrane, and, from the milky appearance of the fluid contained in them, called *lacteals*. As they pass off from the intestines, they unite together and form larger trunks; these proceed backwards towards the spine, where they meet with a number of irregularly shaped bodies, called the *mesenteric glands*, in which they are ramified to extreme minuteness. From these glands, come out several vessels larger than the lacteals, but very similar to them in appearance. These at last join in one common trunk, called the *thoracic duct*. This vessel is about the size of a goose-quill; it lies along the spine running from the abdomen up through the chest, till it terminates in one of the veins of the left arm. To recapitulate in one sentence the course of the chyle;—it is taken up from the small intestines by the mouths of the lacteals; carried by them to the mesenteric glands, where some change with which we are not yet acquainted, is wrought upon it; thence into the thoracic duct, which at last pours it into the veins, where it becomes mingled with the mass of the blood.

Emily.—You speak of the chyle being absorbed by the lacteals, as if they exercised a sort of intelligence in the process. I do not exactly comprehend your idea.

Dr. B.—The principles upon which the lacteals select the chyle from the mass of heterogeneous materials with which it is mixed, have been variously explained by physiologists. In this respect, the lacteals seems to be analogous to the fibrils of the roots in plants, which absorb from the soil those substances only which are proper for the nourishment of the plant. We witness the fact, but in attempting to explain it, we can go no farther perhaps, than to attribute it to the operation of vital, not mechanical principles.—Such is a general sketch of Digestion in man and a few other animals that

nearly resemble him in structure. But the truly philosophical mind, whose object in the study of nature is the attainment of general views, not insulated facts, will not rest satisfied here, but will wish to contemplate this wonderful function in the other orders of being that fill up the great scale of animal existence. In the study of the animal economy, nothing can be more interesting than to trace the various changes which the functions of life undergo, as we follow down the constantly varying forms of organization, from the most perfect and complicated, to the most simple and rudimentary,—to see how some new modification is continually occurring to correspond with other peculiarities of structure, but still answering the same ultimate purpose,—to behold the organs steadily diminishing in complexity, till at last they are one after another totally annihilated.

Emily.—Such general views of the vital functions must certainly give us a worthier idea of the wonder and glory of Nature's works, than to behold them in one order of beings alone. After considering them as they exist in the human structure, no one can help being gratified at seeing how curiously they are varied, so as to correspond with the varying structure and circumstances of the animal.

Dr. B.—In the quadrupeds, or *mammiferous* animals, as they are called by naturalists, the organs of digestion very nearly resemble those of man. In one order, however, the cloven-footed animals, such as the ox, deer, sheep, &c. there is a curious modification of this function, the design of which, or its relation to the general organization of the animals, is not very apparent. They possess four stomachs, the first three of which communicate directly with the œsophagus. After the food has been partially chewed in the mouth, it is swallowed and received into the first stomach. There it is mixed with the fluids that are poured out abundantly from its internal surface, and by this means, and proba-

bly by the motions of the organ itself, it is softened, divided and formed into little pellets.* By the contractions of the stomach, these are made to ascend the œsophagus to the mouth, where they undergo a second and more thorough mastication. Thence it is carried directly to the second stomach, where it experiences some further changes, the nature of which is not exactly known, and then passes on into the third and fourth stomach.

Emily.—I have frequently observed cows chewing their cud, when they seemed to be in quite a complacent, meditative mood.

Dr. B.—It is from this appearance of meditation which they exhibit while chewing the cud, that they have derived the name of *ruminating* animals.—In Birds we noticed a curious peculiarity in the form of the stomach, by which it is endowed with great strength and powers of trituration. But this is not the only peculiarity which they possess in their digestive organs. In those which live on grain and other hard substances, there is a membranous sac in the neck communicating with the œsophagus, called the crop, or craw. Into this receptacle the food is conveyed, and softened by the fluids secreted from the glands with which it is furnished—thence it is carried to the stomach. In some of the carnivorous birds, this sac seems to be merely a dilatation of the œsophagus, and serves as a reservoir in which they carry their food when not immediately required.

In the Reptiles and Fishes, there is nothing particularly remarkable in the structure of their digestive organs. They are fitted, in most of these animals, to digest flesh, and the constitutional sluggishness of the former enables them to abstain from food for a considerable time. Some of the turtles go months and even

* The author has preferred to follow Toggia's account of rumination—opposed as it is to that of Blumenbach, Curvier, &c. and not yet perhaps generally adopted—because it appears to be the most philosophical explanation of this process, and the best supported by facts.

years without eating. Their voracity is sometimes almost incredible. The Boa constrictor and Anaconda swallow animals nearly as large as themselves, and afterwards retire to some obscure place, and remain in a state of stupid inaction while the process of digestion is going on.

In the Mollusca, or shell-fish, the organs of digestion present considerable variety of structure. Some of them only have jaws for mastication. Some are provided with a crop, and a muscular or membranous stomach as in the Birds, and they are probably used for the same purpose. Those without a head, as the clam, oyster, &c. feed only on such nutritious matters as are brought to them in the water. The lobster, crab, &c. are remarkable for having their teeth placed in the stomach instead of their jaws.

Emily.—An arrangement which has one convenience at least—the creature is saved the trouble of moving them. But, pray, how are they used?

Dr. B.—They are situated on opposite sides of the stomach near its lower end where it begins to grow narrow, and being moved up and down by the action of this organ, they thoroughly grind up the food which passes between them.

In the Zoophytes where the whole internal parts of the animal constitute the digestive cavity, there is no distinction of the process into chymification, chylication, &c. but it is all performed without any distinct stages, and the chyle instead of being taken up by a particular set of vessels, transudes through the sides of this cavity and bathes the whole body. Some of the *medusae* instead of a single mouth, are furnished with numerous branched feelers, each perforated by a small opening. Each opening leads into a small canal which joins a neighboring one, and so on till four large trunks are formed which end in the stomach and convey to it the matters absorbed by the apertures of the feelers. The number of the latter is sometimes eight hundred.

Emily.—This is a very close approximation to the mode of nourishment in vegetables, for these feelers seem to act very much like the roots of plants.

Dr. B.—The economy of the Zoophytes evidently manifests an approximation to that of vegetables. Those *sea-anemones* which are in the form of a ray, the whole interior surface constituting the digestive apparatus, may be turned inside out, and the food digested just as well as before by the external surface. Some plants, you know, may be planted with their branches in the soil and their roots in the air, and after a time, the former will be converted into true roots, and the latter will put forth leaves and blossoms.

We have now terminated the history of digestion. Before we can follow the nutritious portions of our food any farther, we must consider the function of *circulation* as it is called, and the organs by which it is carried on. But we have already greatly exceeded our usual time, and must defer this subject till to-morrow.

CONVERSATION IV.

Circulation—the blood—connection of circulation with respiration—blood-vessels—heart, arteries, veins—motion of the heart—anastomosis of arteries—the pulse—influence of disease on the pulse—the lesser or pulmonic, greater or systemic circulation—capillary system—inflammation—adhesion.

Emily.—To day we are to have some account of the *circulation*; but I hope you will first favour me with an explanation of this term. I cannot conceive what this allusion to a circle can mean.

Dr. B.—The function derives its name from the circumstance that the organs are joined together in such a way that there is properly neither beginning nor end; but as it regards the function itself, they are connected in a complete circle. Their use in the vital economy is to convey different materials from one part of the system to another; to receive the chyle from the thoracic duct and expose it to the action of the respiratory organs; to take up particles of the body which are no longer fitted for its purposes, and carry them to the excretory vessels to be thrown out of the system; and finally, to repair the waste of the organs with suitable materials of supply. The fluid which they contain, thus made up of heterogeneous materials, is called the *blood*, and is found in all animals that possess a circulating system, though

under different appearances. In the first place let us examine the properties of the blood, and then we will look at the heart and vessels by which it is circulated.

The most remarkable property of the blood, is that of its coagulating when drawn from the vessels. This process seems to be independent of external causes, and has never been satisfactorily accounted for by physiologists.

Emily.—May it not be because it is at rest, instead of being in a state of constant motion as it is in the body? Or perhaps it is a kind of freezing process, produced by its exposure to a less degree of warmth than the temperature of the body.

Dr. B.—By exercising your ingenuity in this way, you might fabricate many other theories, all which have been already anticipated, and all equally incapable of explaining the effect in question. The coagulation of the blood is not prevented by keeping it constantly agitated after it is drawn, and is rather hastened than retarded, by exposing it to a degree of heat less than that of the body. The celebrated John Hunter thought he explained it, by saying that the blood possessed life, and that coagulation was a vital process. As it is a process of a very peculiar nature and one of great use in the animal economy, it may not be improper to give it that name; but it is very probable that the causes on which it depends are of a physical nature. It is a little remarkable that in animals which have been run to death, or killed by lightning, the blood loses entirely its power of coagulation.

Emily.—These are the same conditions under which the muscles lose their contractility after death. May not the cause be the same in both? The coincidence is too singular to be accidental.

Dr. B.—It is very probably as you suggest, but the cause whatever it may be, is thereby no better made known. If you have ever observed a quantity of blood, an hour or two after it has been drawn, and suffered to

remain at rest, you have found it separated into three very distinct portions, viz. the *serum*, a thin, watery fluid ; the *fibrine*, a thick, tenacious, jelly-like mass floating on the surface of the serum ; and a quantity of *red globules* which adhere to the under surface of the mass of fibrine.

Emily.—I recollect having observed some blood a short time after it was drawn, and was surprised to find that it had completely lost its fine dark red tint, and became almost colorless. I suppose that if I had raised the cake of fibrine, I should have found the red parts, which had so mysteriously disappeared. But what is the composition of these different portions ?

Dr. B.—The constituent principles of the serum, are *water*, *albumen* and a small quantity of *soda* ; those of the fibrine, are *fibrine*, a peculiar animal substance, and a small portion of a few *saline* and *animal* substances ; the red portion of the blood is thought to resemble *fibrine* and contains also, *iron* and *sulphur*, in very small quantities.

Emily.—This is wonderful indeed. I cannot imagine in what manner iron and sulphur can get into the blood, for we certainly take neither of these substances with our food.

Dr. B.—It is so difficult to account for their uniform appearance, that it has been supposed the iron was formed in the process of analysis. Their aggregate quantity in an individual has never been determined with much accuracy. By one or two experiments it has been estimated at three ounces, the whole quantity of blood being about twenty four pounds.—Another curious fact in regard to the blood, is that it is composed of minute globules similar to those which form the elementary tissues.

Emily.—Is the blood of the inferior animals like that of man ?

Dr. B.—Chemical analysis detects no difference, though some difference no doubt, exists. It has been found that a dog may be bled till all sensible manifestations of life have disappeared, and restored immediately

to perfect health by injecting into its veins the blood of another dog, while that of a man or horse would be followed by little or no benefit. On the whole, the blood may be considered as the most important of the animal fluids, being the grand source whence the system receives the needful supplies to repair its waste and maintain its growth.

In all animals that possess a circulating system, we find at the same time, an apparatus for the function of *respiration*, and the *quantity*, or degree of perfection of one of these systems is in direct proportion to that of the other. As the blood in its passage through the body loses much of its nurient materials, and acquires others that are no longer fitted for the purposes of life, some provision is evidently required by means of which it may throw off these useless portions, and receive continual renovation.

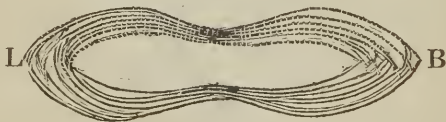
Emily.—And this provision is furnished by the lungs. I have now a more definite idea of the use of these organs and their connection with the circulation, than I ever possessed before. I begin now also, to perceive this beautiful system of harmony of action and mutual dependence, which associates the various organs of the body in one great and perfect whole.

Dr. B.—You now readily see the necessity of the blood's being constantly submitted to the action of the respiratory organs, and as constantly changed by this action. Every portion of blood before being sent to the body must be carried to them, and the essential use of the circulating vessels, *considered in their simplest condition*, is to convey the blood from every part of the system to the lungs, and thence back to the system again. Here then is a perfect circle of action which is incessantly going on from the beginning to the end of existence.

Emily.—What a multitude of vessels must be required thus to carry the blood to and from every and the

minutest portion of the body ! I am quite impatient to know more of these curious organs.

Dr. B.—The blood vessels are strong membranous tubes composed of three coats. The external is formed of cellular substance ; the middle of muscular ; and the internal is one of a peculiar nature, possessing considerable elasticity and power of dilatation. In their course they are constantly subdividing and giving off branches, until from being larger than a man's thumb at their main trunk, they become at their extremities of a size almost imperceptible. They are distinguished into two kinds ; one conveying the blood from the lungs to every part of the body, called *arteries* ; the other, conveying the blood from every part of the body to the lungs, called *veins*. Each of these sets of vessels may be compared, in their disposition, to two trees united by their trunks, the branches of one originating in the lungs, the other in every part of the body. In order that you may have a perfectly distinct idea of the relative situation of these vessels, I have prepared this diagram* in which the dotted lines represent the arteries, and the others the veins. You see the branches of the arteries originating in *L* the lungs, running together till at last they form one larger trunk, and again branching off to terminate in *B*, or every part of the body. The veins originate where the arteries



terminate, run together and form one larger trunk, branch off again, and finally extend their minute ramifications to every part of the lungs. This now, constitutes all that

*The reader must bear in mind the distinction between a plate and a diagram. The former is a representation of the actual appearance of an object ; the purpose of the latter is merely to illustrate some particular principle, or manner in which an object acts, without adhering at all to the exact form or appearance of the object.

is necessary to the simplest form of the circulation—a set of vessels to carry the blood to the lungs, and another to distribute it to the body.

Emily.—Thus far, I believe, I understand the matter perfectly well, but I cannot conceive by what means the blood is moved through the vessels ; unless that it be by the action of the vessels themselves, and yet I have always supposed that the heart was connected in some way with the motion of the blood, but you have not spoken of it.

Dr. B.—I have purposely avoided speaking of it, in order that your notions of its relation to the circulation might not be confused by introducing it before you were properly prepared to understand it. Have patience one moment and you shall understand all. In this diagram the blood is supposed to be moved solely by the power of the vessels themselves ; no other is present to assist them. Now, in some of the lower orders of animals, this is precisely the manner of the circulation—the power of the vessels without any other aid, is sufficient to propel the blood through them. But if we ascend the scale of being to where the organization has increased in complexity and perfection—where the vital energies possess more activity and strength—where consequently, a greater degree of action is required in the apparatus which is to support the vital energies and repair their losses, we find an additional force is provided to assist the action of the vessels. Now then, you probably can tell what this force is.

Emily.—I presume it must be the heart, if this organ is concerned in the motion of the blood, for I cannot see what other use it can have.

Dr. B.—You are right ; and since you have comprehended the subject so well thus far, you will perhaps perceive at once in what part of the circle the heart should be placed, in order that it may act with the greatest advantage.

Emily.—Undoubtedly it would be where the two

trunks are united together. But still, I have no idea how the heart is formed so as to be made a moving power, nor whence it derives its power.

Dr. B.—The clearest idea that we can have of the nature and purposes of the heart, is by considering it as it exists in its simplest condition in the inferior animals, merely as a hollow muscle placed somewhere in the circle, through which the blood passes and receives from its impulse an increased rapidity of motion.

Emily.—I had forgotten to ask whether it was in the trunks of the veins or arteries that the heart is placed.

Dr. B.—A question well asked, for the position of the heart in respect to the other parts of the circulating system would not be a matter of indifference. The truth is that the heart considered merely as a moving power, may be placed either where the venous, or the arterial trunks join. In the former case, the blood will be driven with increased impetus towards the respiratory organs, but its motion in the arteries will be unaffected by it. In the latter case, the blood will be propelled with accelerated force towards every part of the body, while its progress in the veins remains unaffected. Instances of the heart in each of these two different positions may be found in the inferior animals—in fishes, of the first position; in some of the shell fish, of the last. Now there is nothing necessarily to prevent there being a heart in each of these situations, and thereby the progress of the blood be accelerated in both directions. Such is actually the case in some of the mollusious tribes, as the *cuttle fish* and *nautilus*. Here is a diagram illustrating this form of the circulation. If now we consider these two hearts brought together and joined by their sides, their cavities still remaining distinct, we shall have the heart as it exists in man, quadrupeds, birds and some reptiles. It is therefore far from being a single heart, but is strictly a double heart—two single hearts united together.



Emily.—Few people, I suspect, imagine that they have, to all intents and purposes, a couple of hearts.

Dr. B.—If we were to judge by the frequency with which they lose them, they *ought* to have a score. Let me now call your attention to the human heart.

The double heart of man is situated in the lower and front part of the chest and a little to the left side. It is of an irregular, pyramidal shape, with its base upwards and its apex pointing obliquely downwards, and is enclosed in a membranous bag called the *pericardium*, which fixes it in its place, and protects it from the contact of other organs. Being double it is generally distinguished into the left and right hearts, or, to use names which at the same time give an idea of the relative office of these parts, *arterial* and *venous* hearts. Neither of these hearts is formed by a single cavity, but each is composed of two cavities. The larger is called the *ventricle*; the smaller is merely an appendage to the other, and is called the *auricle*. The walls of the ventricle are exceedingly thick and strong. Their internal surface is very irregular, owing to numerous little, fleshy columns, which run in the direction of the length of the ventricle, in bass relief. They are endowed with great contractile power, and act with immense force in bringing together the sides of the ventricle. Each ventricle presents two apertures—one by which the blood is admitted into it, and the other by which it is sent out. The auricle is much smaller than the ventricle, the sides are thinner, and its fleshy columns are less powerful.—Now, we will follow the blood in its course through the hearts, and you will see some curious contrivances by means of which they exert a force on the motion of the blood.

First, let us trace it through the venous heart. The venous blood, after being brought from every portion of the body, is at last collected into two great veins, the one ascending through the abdomen with the blood of the lower parts of the body, called the *vena cava inferi-*

or; the other descending with the blood of the head, chest, and upper extremities, called the *vena cava superior*. The two veins discharge their contents by a common opening into the right auricle. This cavity being excited by the presence of the blood which completely fills it, contracts suddenly and strongly upon the mass within. Being pressed in all directions it will escape wherever it can find an outlet. Now there are but two openings into the auricle—the one by which the blood gained admittance, and the other leading into the ventricle. Through the former it is impossible for it to escape, except in very small quantities, because a long column of blood is in these veins, presenting too great a resistance to its escape in that direction. The latter opening—that into the ventricle, is now the only one left, and this, as soon as the auricle begins to dilate, presents a free and open passage into the ventricle.

Emily.—But why does not the blood flow directly through this opening while the auricle is filling? I see nothing now, to prevent it.

Dr. B.—You will see in a moment why it does not; but first we must trace it into the ventricle. This cavity when filled, like the auricle contracts upon the blood, which must find an outlet either back through the opening into the auricle, or into the vessel which carries it to the lungs, called the *pulmonary artery*. A very ingenious though simple contrivance effectually prevents it from passing back again into the auricle. From every part of the circular opening between these two cavities, arises a thin, light membrane cleft almost down to its roots, in three places, thus dividing it into three separate pieces. These pieces are still farther divided, giving the membrane a fringe-like appearance. These fringes are connected to the walls of the ventricle by many little tendinous strings sufficiently long to allow the fringes a considerable extent of motion. Now when the ventricle contracts, the blood driven in all directions insinuates itself behind these fringes, and raises

them up as far as their tendinous strings will permit. This is sufficiently far for all the fringes to meet one another, and thus form a perfectly impervious membrane stretching across the opening. When the ventricle dilates, the fringes are pulled down by the separation of the walls to which they are tied, and they hang loose in the ventricle till they are again raised by its contraction. Thus, you observe, they act the parts of valves, and are called, *tricuspid valves*, from the pointed appearance of the three main pieces.

Emily.—Ah, now I perceive why the blood which fills the auricle does not run directly through it into the ventricle. While the auricle is filling, the ventricle is contracted and expelling its contents, so that the same valves which prevent the blood from escaping into the auricle, also prevent it from escaping into the ventricle before the auricle is filled. Is not this correct?

Dr. B.—Yes; and now having a clear idea of it thus far, you will comprehend the rest with very little difficulty. The blood has now been pushed into the *pulmonary* artery, but some contrivance is obviously required to prevent the blood from passing back again into the ventricle while it is dilating. This object is also effected by valves. Just at the mouth of the artery, are three thin, strong membranes of a semi-lunar shape, with their loose edges hanging free in the cavity of the artery. The blood in the artery pressing in all directions, raises these valves till their sides are brought together, and thus the cavity of the artery is completely closed up. Being prevented from passing in this direction, it flows on through the pulmonary artery, and is finally distributed to every portion of the lungs.

Emily.—I cannot see with what propriety you call this vessel an artery, for it certainly conveys venous blood.

Dr. B.—It carries venous blood, indeed, but it has the structure of the arteries, and its course is *from*, not *to*, the heart. For the same reason, the vessels which

collect the blood from the lungs and transmit it to the heart, are called *veins* instead of *arteries*. Having now been submitted to the action of the lungs, it is taken up by a multitude of minute vessels, which are continually joining one another in their course, till they finally form four large trunks, called the *pulmonary veins*. They come two from each side, and enter at opposite sides of the arterial auricle. Thence the blood is transmitted to the arterial ventricle, the opening between which and the auricle, is provided with a valve, whereof the construction and use are very similar to those in the venous heart. The valve here, however, is only twice cleft, and from a fancied resemblance to a mitre, is called the *mitral* valve. The arterial ventricle is longer, stronger and thicker, than the other, but in all other respects, it closely resembles it. The contraction of the arterial ventricle forces the blood into the *aorta*, the grand trunk of the arterial system. This vessel is also furnished with semi-lunar valves, in the same manner as the *pulmonary* artery. The venous auricle and ventricle are more capacious, but possess less power of contraction, than those of the other side, for having to send the blood only to the lungs, which are but a short distance from them, an equal degree of force with that exerted by the others which throw it over the whole body, is obviously not required. This completes our account of the heart, and the course of the blood through its different cavities.

Emily.—Before we leave this part of the subject, please to enlighten me on one point about which I am uncertain. The cavities of the two hearts, you observed, were perfectly distinct—without the slightest communication. Now, though I do not doubt the fact, I am at a loss to see the reason of it.

Dr. B.—If you were fully acquainted with the nature of respiration, you could not be at a loss one moment, to perceive what mischievous effects such a communication would produce. Venous blood, you know, would be mixed with arterial, and blood which has not

been subjected to the action of the lungs, and consequently unfit for nutrition, would get into the arteries, and be distributed to the body. Sometimes, such a communication does exist from birth, and from the peculiar appearance of the subjects in which it takes place, they are called *blue boys*. They seldom survive long; most of them dying in a few hours, though some have lived two, three, and even seven, or eight years. The effects of such a communication were strikingly illustrated in a patient who died a few years ago in one of the Parisian hospitals, in whom it had been produced by a disease of the heart. At this time he was forty-one years of age. His face was remarkably livid, the vessels were injected with blood, his lips were unusually large, and like the rest of his body, were of a deep blue color. His respiration was laborious, his pulse extremely irregular, and he was unable to articulate two words in succession, without stopping to take breath. He was obliged to sleep in a sitting posture, and was particularly remarkable for his indolence. This indolence, joined to great natural simplicity, was such that he could not do without the assistance of his wife. He finally died from suffocation. The lividity was occasioned by the dark venous blood that had entered the arteries, and which, unable to afford the necessary stimulus to the powers of life, produced his uncommon indolence.

Emily.—The action of the heart is incessant, is it not, enjoying no moments of repose or relaxation of duty, like some of the other organs? The mischief that would follow an entire cessation of its action, is very obvious, but I do not understand why such an arrangement was necessary.

Dr. B.—Or in plainer language, why is the body made—just as it is made? This is the legitimate extent of your question when carried out. Now, that the body might have been so constructed as that the circulating system should have had its periods of repose, is perhaps possible. That it might have been constructed without any circu-

lation at all, if the Great Architect had so pleased, is also possible. But all this is none of our business. We are to take the animal economy as we find it, and rest satisfied with the beauty and wonder which we observe. That the constant action of the heart is necessary, is certain ; how it is so constituted as to commence its labours with the first visible signs of organization, and finish them only with the last moments of existence, without causing a feeling of fatigue, is a question not so easily answered ; but the fact is no more wonderful, than that the stomach should act without giving the sense of fatigue.

Emily.—But does not the action of the heart cease during fainting ? Such is my impression, and if the fact be true, I see not how to reconcile it with what you have said in regard to the disastrous consequences which such an accident would produce.

Dr. B.—True indeed, its action may cease during fainting for a moment, and then be resumed ; but it is only for a moment—if the interval be protracted, the blood coagulates in the vessels, and its motion is thus effectually prevented.

Emily.—How then do those persons ever recover, who for three or four days, have lain in a trance as it is called, and apparently dead, for the least sign of life cannot be perceived ?

Dr. B.—They were not in fact dead ; neither does the heart, in such cases, entirely cease, though its action is so feeble, that unless it be closely examined, it will escape our notice, as has been the case in all these instances.

Emily.—Still, there does appear something very singular about the action of the heart—something altogether different from that of other organs. Pray, Dr. B., whence does it derive the power which imparts such astonishing constancy and accuracy to its motions. This is inexplicable to me.

Dr. B.—Not only to you, but to physiologists, from the earliest times, to whom it has always been a cause

of much wonder and doubt, and as might have been expected, has elicited much wild and visionary speculation. The ancients thought there was an innate fire in the heart, which produced its motion, and a chemical sect attributed it to an effervescence in the heart, caused by the mixture of different kinds of blood. You smile at such absurdities, but they can teach you an all-important truth, which cannot be too strictly adhered to—never to reason on scientific subjects, without having first carefully considered all the facts connected with the case in question, and then deducing cautiously the general principles that arise from them. This is the basis of all true philosophy. The most that we know of the motions of the heart is, that they are under the influence of the nervous system in a very great degree, and particularly of that portion of it which is connected with the spinal marrow.

Emily.—What ground is there for even this fact?

Dr. B.—In the first place, it is inferred from the fact, that animals have been born without a brain, in which the heart and the rest of the body were perfectly well formed,—a proof that the heart derives its nervous power from the spinal marrow, and not the brain. Secondly, it is inferred from the experiments of Le Gallois, who ascertained that though a creature's head were cut off, yet if the bleeding vessels were tied up, and artificial respiration maintained by blowing air into the wind-pipe from a pair of bellows, the heart would nevertheless continue to act for a considerable time after the decapitation of the animal. This is about the sum and substance of all we know concerning the source of the heart's power.

Emily.—As the blood is incessantly revolving in a circle, it must be continually returning at certain periods to the place whence it started. Now, I am desirous to know how long a time is required for a given quantity of blood to complete the revolution.

Dr. B.—If you suppose that the arterial ventricle contracts seventy-five times in a minute, expelling two ounces,

Troy weight, at each contraction, and the whole quantity of blood in the vessels to be thirty-three pounds, you will have no difficulty in answering the question yourself.

Emily.—One hundred and fifty ounces, or twelve and a half pounds, will be expelled from the heart each minute, consequently thirty-three pounds in two minutes and thirty-six seconds, so that the whole mass of the blood will go the round of the circulation twenty-three times in an hour. What astonishing rapidity!

How wonderful that in so small a space of time, every portion of blood sent out from the heart goes to the body, thence to the lungs, and finally back to the heart again. And with what astonishing force too the heart must act to propel so large a mass!

Dr. B.—This great power has always excited the attention of physiologists, and at a time when mathematical calculations were greatly in fashion in medical science, many attempts were made to ascertain its exact quantity. One philosopher performed a great many experiments, and went through many tedious calculations to ascertain the power with which the heart expelled the blood, and lo the result! He found it equal to one hundred and eighty thousand pounds! Another, after going over a field of investigation full as extensive, came to the conclusion, that it was—five ounces and a half! Another estimated it at fifty pounds, in which estimate he probably came nearer to the truth than either of the others.

Being the most essential of all the organs, the heart is the first one formed in the organization of the higher animals. If the egg of a bird be examined in the first periods of incubation, the heart will be seen a hardly perceptible speck, having already begun its motions, before the rudiments of any other part can be observed. Many of the other organs are sometimes found wanting, but never the heart. Here it is, beating on untired from the beginning to the end of life. This finishes our account of the circulation through the heart.

Emily.—Now, I suppose we are to trace it in its pro-

gress to the various parts of the body, as it is carried along by the arteries. What a multitude of these vessels there must be ; it would be impossible to remember all their names.

Dr. B.—And we can see but a small portion of that system of vessels which transmit their contents to the minutest point in the body, insomuch that not the slightest scratch, nor prick of the finest needle can be made, without wounding them, and producing an effusion of blood. The aorta, constituting the great trunk of the arterial system, rising up from the arterial ventricle, and suddenly bending over, passes straight down the trunk of the body and lies near the spine. From its arch, it gives off several large vessels which go to the arms, neck and head, viz. one to each arm, called the *subclavian arteries*, and four to the neck, face, and head, the two *carotids*, and two *vertebrals*. The branches sent off by these vessels supply all these parts. In its passage down the trunk, it sends branches to the stomach, liver and spleen, and the other internal organs. In the lower part of the abdomen, it divides into two, called the *iliac arteries*, which supply the neighboring organs, and the inferior extremities. The arterial branches are generally given off at acute angles ; sometimes however at right, and in a few instances at obtuse angles. The branches are smaller than the vessels from which they are given off, and thus the vessels go on decreasing in size, even to their minutest ramifications.

Emily.—But as the branches taken together have obviously a greater diameter than the trunk itself, the motion of the blood must be continually grower slowing, according to a well known law of the distribution of forces. The zig zag direction of some of the vessels, and the great size of the angles at which they are given off must also have a tendency to retard its motion. But I have observed, in a plate of the arteries, two bending towards each other and at last forming but one vessel ; others are connected by a branch running between them.

The former sort of communications must accelerate the motion of the blood, for you know when a fluid passes from a larger into a smaller channel, the forces by which it is impelled remaining the same, its progress is quickened.

Dr. B.—These arterial communications are called *anastomoses*, and are very useful, in supplying organs and parts from which, by any cause, the usual supplies are cut off. This utility is very manifest in diseases of vessels which require them to be tied. Thus the two great arteries which go up along the sides of the neck, meet together in the base of the brain and form a single vessel, so that if one of these vessels be tied, the brain, you see, will be supplied with blood just as well as before.

Emily.—But it certainly cannot receive so much, because it is evident that one vessel cannot transmit so much blood as two.

Dr. B.—This difficulty is obviated by a very admirable law of the human economy. When an artery is tied or otherwise obstructed, the neighboring vessels enlarge their calibre, so that they ultimately transmit to the parts as much blood as they received before. Such is this singular power of the vessels to accommodate their capacity to the wants of the system, that modern surgeons have presumed upon it to an almost incredible degree, and with such beneficial results as to redound greatly to the honour of their art. When an artery is diseased, even though it be the chief artery in the limb, they do not hesitate to tie it up, to prevent it from bursting its coats and killing the patient by a terrible hemorrhage. Sir Astley Cooper once tied up the aorta itself in the abdomen just before it divides into the iliacs, and though his patient died a few hours afterwards, he attributed his death to the disease rather than the operation.

The position of the arteries evinces that great precaution has been kept in view for their security and protection against external accidents. They generally lie deep

seated far beneath the muscles, and close to the bones, and are never found in places where they would be exposed to injuries. Thus, no large arteries are found on the back or face; those of the chest run along on the inner side of the ribs, and those of the legs where accidents are frequently occurring, are very deeply seated near the bones and are difficult of access.

Emily.—But, Dr. B., are the arteries entirely passive, as it respects the motion of the blood? As the heart, according to your definition, is a power whose object is merely to *assist* the motion of the blood, I still presumed that they had *some* share in the duty.

Dr. B.—The motion of the blood in the larger arteries is derived entirely from the impulse of the heart, but in the smaller branches it is chiefly effected by the action of the vessels themselves. It may be stated generally, that as we proceed from the heart we find its power diminishing, and that of the arteries increasing, until we arrive at the extremities of the vessels where the force of the heart is nothing. Though the blood is thrown into the arteries at intervals, yet they are always full—the cause of this, I suppose, I need not point out to you.

Emily.—If I am not mistaken it is because a column of blood being displaced, no greater than that which enters the vessels at each contraction of the ventricle, they will be equally full during both the contraction and dilatation of the heart. But will the motion of the blood be uniform?

Dr. B.—Certainly not, for during the dilatation of the heart, its progress must unavoidably be slackened, and if a puncture be made in an artery the blood will gush out in regularly successive jets. If the motion of the blood were uniform, it would flow out in a steady stream. This flowing of successive waves of blood may be easily perceived by placing the finger over an artery, and pressing upon it with sufficient force to diminish its calibre slightly. This presents an obstacle to the free passage of the

blood, and the finger will feel it very distinctly moving along. Find the artery which runs along the upper side of the wrist and try it for yourself,—there.

Emily.—Why this is the *pulse* which I have felt a thousand times before. This phenomenon, then, which has always appeared so mysterious to me, is nothing but the successive waves of blood impinging against the sides of the artery which is compressed by the finger. As the whole mass of the blood is put in motion at each contraction of the heart, the pulse must consequently be felt at the same time over the whole body. This is a new fact to me also. Pray tell me, Dr. B., what there is about the pulse, which requires physicians to feel it, at every visit they make their patients? Much as I have learnt about this subject, this still has an air of mystery about it to me.

Dr. B.—The intimate relations and nice sympathies that exist between the heart and every other organ, are such, that the slightest derangement in any of them, generally affects the action of the heart. Now the pulse is the index of the power and number of the heart's contractions; of the quantity of blood thrown out; and consequently of the general condition of the system, relative to health and disease.

Emily.—Ah, this clears up the mystery, and accounts at the same time, I suppose, for the grave, wise-looking face which the doctor puts on in the act of feeling the pulse. You remarked just now, that the heart contracts seventy-five times in a minute; is this the exact number of the pulsations in a state of health?

Dr. B.—This varies according to climate, age, sex, health, &c. The common standard of an adult male however, in good health, is about seventy; but owing to difference of temperament, habits of living, &c. it generally varies from sixty to eighty. Dr. Heberden mentions a person whose pulse did not exceed sixteen; and an old writer speaks of one, whose pulse was not more than ten beats in a minute. At birth, it is as many as one

hundred and forty ; but as the child grows older, the circulation slackens, and at two years of age, it has become reduced to one hundred. At twelve or fifteen, it is about eighty, and in old men, it is generally below sixty. In women, the pulse is generally ten or twelve strokes quicker than in men. In weakly and irritable frames, the pulse is considerably above the common standard. The cheerful passions and affections, such as joy, love, and sudden pleasure, generally accelerate the heart's action, unless carried to excess—then it seems to be overwhelmed by the magnitude of the feeling, and sometimes ceases to beat forever. The depressing affections, such as grief, fear, melancholy, &c. retard its action, and the sudden news of some unexpected disaster, has arrested it forever.

Emily.—Does the presence of disease in the body, vary the heart's pulsation in regard to number merely ? If you will allow me to hazard a conjecture, I should think that the force and quickness of the heart's contractions might be liable to variations from this cause, and thus the pulse be affected.

Dr. B.—You are perfectly correct in your conjecture ; and the various kinds of pulse produced in this way, have received appropriate names from physicians. For instance, when the artery appears under the finger as it increased in calibre, and transmitting a greater column of blood, it is called a *full* pulse ; the opposite is styled the *small, contracted* or *wiry* pulse, the artery feeling as if it was contracted to the size of a thread, or wire. When a very slight pressure is sufficient to prevent the passage of the blood through the vessel, the pulse is said to be *soft* ; it is called *hard* on the contrary, when the artery is not easily compressed. In short, the presence of disease in the body varies the action of the heart to infinity.

Emily.—The heart then must possess very numerous and close connexions with the rest of the system, does it not ?

Dr. B.—Excepting the digestive system, no organ possesses such close and extensive sympathies, as the heart. The least degree of constitutional excitement is propagated to the heart, and is manifested in a modification of its actions. Thus you may easily conceive that the pulse should afford to the physician one of the surest criterions in judging of the nature and severity of disease. The circulation of the blood was discovered in 1620, by Harvey, and the immense advantages, which this discovery has given to modern physicians, are of more value than all the accumulated discoveries and observations of all his predecessors.

Emily.—Before quitting this part of the subject, I wish to ask a question which I have been expecting all along your explanations would render unnecessary. I want to know if the heart is the seat of any of the passions, or moral affections; we hear every day you know, of a *good heart*, a *bad heart*, a *kind heart*, an *open heart*, &c.

Dr. B.—Such indeed was the belief of the ancients, and also of one or two modern physiologists, and though the notion is exploded now, yet the language which it gave rise to is still retained. It originated from the fact, that in violent passions the heart is more or less affected in consequence of its sympathy with the brain. The heart does not seem to be endowed with common sensibility, for Richerand a distinguished French surgeon, in one of his operations, exposed the heart and touched it with the handle of his knife, without the patient's experiencing any sensation whatever.

Emily.—So far then as the seat of the feeling is concerned, we may with equal propriety say of a person, that he has a *good*, or a *kind liver*, as a *good* or a *kind heart*. But please to resume your account of the circulation which I so unceremoniously interrupted.

Dr. B.—I was about to follow the blood in its course through the *veins* whose office it is, to convey it to the respiratory organs. The veins are much more numerous than the arteries, for arteries of a middle size are

generally accompanied by two veins ; their aggregate capacity is consequently greater, and the blood which they contain bears the proportion of 9 to 5, to that in the arteries. Their course is straighter and they more frequently anastomose than the arteries. The larger veins are generally enclosed in a common sheath with the artery that is going to the part whence the vein has come ; the smaller veins are unaccompanied by arteries and are more superficial in their situation. The blood brought from all parts of the system, is collected, as we have before observed, into two great trunks which pour it into the venous auricle of the heart.

As the circulation has now been described, it may naturally be divided into two parts, or stages, in reference to its relation with the heart, viz. from the heart, through the lungs, back to the heart ; then through every part of the body, back to the heart again. The former portion of the course is called the *lesser*, or *pulmonary* circulation ; the latter, the *greater*, or *systemic* circulation.

Emily.—You do not mean certainly, that there are two complete circles described by the course of the blood ?

Dr. B.—No ; but that the course is rather represented by the arcs of two circles, one larger than the other, connected by their extremities, in this manner. Here you see that from whichever ventricle the blood is sent out, it does not return to the same ventricle till it has completed the whole circulation, both greater and lesser.



Emily.—I do not understand how the blood is moved in the veins contrary to its own gravity, as it is in some parts of the body, for you said that the action of the heart ceased in the smaller arteries.

Dr. B.—This indeed is a very obscure point in physiology, though the theories that have been made to explain it, have been neither few, nor lacking ingenuity. Some have attributed it to the pressure of the atmos-

phere ; some, to the vacuum produced by the dilatation of the venous auricle ; some, to muscular action ; and some to the sole and unassisted action of the veins themselves. Perhaps if the truth were known, each of these agents would be found to have a share in producing the effect in question.

The knowledge of the course of the blood has been of signal service to surgeons, as well as physicians. The older surgeons, when they cut off a limb, had no means of arresting the flow of blood from the divided vessels, but that of searing the stump with a hot iron. This answered the purpose for a day or two, but then it generally broke out again, so that the surgeon was kept in constant dread of a secondary hemorrhage which would destroy his patient's life, before his assistance could be given. Now, the surgeon ties up the vessels with a piece of silk, and goes away without any apprehension of being called again to see his patient floating in his own blood. Besides, if the blood should gush out again, it can be instantly checked without waiting for the surgeon to come and tie up the vessels ; for knowing the course of the blood, all we have to do is to press upon the artery and the flow of blood stops at once.

Emily.—And this is something which would be exceedingly useful to other people as well as surgeons to know, for wounds of the vessels sometimes would destroy a person, before the surgeon could arrive and stop the bleeding. But, Dr. B., how is every body to know the situation of the artery which is to be compressed ?

Dr. B.—If it is not so superficial that it can be felt, as it is in the wrist, a bandage, or a common handkerchief tied tight round the limb, will effectually stop the flow of the blood. Recollect however, that it is not indifferent on which side of the wound you use the compression.

Emily.—That would depend on the kind of vessel. If an artery were wounded, the compression must be

made between the heart and the wound ; if a vein, the wound must be between the heart and the pressure. But I confess, I know not how I should ascertain whether it was a vein or an artery that was wounded.

Dr. B.—When blood flows from an artery, it is by jets, like air from the nose of the bellows ; but from a vein, it is in a steady stream. The superficial veins however, which are the ones most frequently injured, are so small that they seldom give much trouble, or when cut off, they contract and thus prevent the escape of blood.

Emily.—I do not yet understand enough of the subject to see why a physician, when he bleeds a person, always puts a cord around the arms just above where the opening is to be made.

Dr. B.—By so doing, the blood is prevented from passing along to the heart, and accumulates below the ligature, so that when an opening is made, it gushes out very freely. If no ligature were put round the limb, a little blood it is true, would escape from the opening, but the greater portion would pass by towards the heart. Hence, if after the physician is gone, the bandage should get loose, and the blood start afresh, you would stop it by putting the cord around the limb on the other side of the opening. But it is time for us to see how the blood is affected in its passage through the lungs.

Emily.—But first let me ask what purpose is answered by the blood's going to every part of the body, if it passes from the arteries directly into the veins with all possible speed.

Dr. B.—The minute arteries do not terminate directly in the veins—at least, all of them do not—but between these two sets of vessels, we find a third set forming a most delicate and intricate net work, and from their extreme minuteness, are called *capillary* vessels. Though they communicate with both arteries and veins, yet from their infinite division and ramification, and their peculiar powers, they require us to consider them as an

entirely distinct system. So extensive is their distribution, that the most important organs of the body seem to be almost wholly made up of an immense network of capillary vessels. Owing to their exceeding minuteness, some of them carry only the colorless portions of the blood, the red globules being too large for their calibre. In inflammation, where the vessels are enlarged, those which before transmitted only the colorless portions, may now be seen carrying the red globules—as you may have observed in inflammations of the eye. The motion of the blood in these vessels is beyond the influence of the heart, and under the entire control of the vessels themselves. This independence of action may be witnessed in those distributed to the face, which a sudden emotion of mind will distend to redness with the rapidity of thought.

Emily.—And pray, Dr. B., what may be the office of this extensive system of vessels? One would think they were designed for some very important and wonderful end.

Dr. B.—And he would think perfectly right, for they are the seat of some of the most important functions in the animal economy. From them the peculiar fluids are secreted, the body is nourished, and many other processes are probably accomplished which the researches of physiology have not yet unfolded to view. Their number is considerably greater, where secretion is to be performed, than where their object is only the nutrition of the part. It is for this reason that the liver, stomach, &c. which secrete certain fluids that are essentially necessary to the system, are supplied with a greater quantity than the bones, ligaments and skin.

Their action in repairing injuries of parts, is one of great use in the animal economy, and presents some very interesting and curious facts. When any part is injured, the capillaries are enlarged and distended with blood; serous and fibrous portions of the blood are poured out; and heat, pain, redness, and swelling are soon

developed. This phenomenon is called *inflammation*, and seems to be a process or action set up in the part for the purpose of restoring the natural condition, for if it does not take place, the injury is never repaired. This restorative power is beautifully exhibited in cases of wounds made by clean-cutting instruments. If the edges of the wound be immediately brought together and retained in this position, a quantity of fibrine is thrown out from the capillary vessels, which glues the sides of the wound firmly together ; vessels shoot out from either side into this mass, meet those of the opposite side, and thus establish a free circulation through it ; the firmness and sensibility of other parts are shortly manifested, and it is at last decidedly and completely organized. It is astonishing to see with what rapidity this process is sometimes performed ; the adhesive matter was found in one case, to have become completely organized in twenty-nine hours.

Emily.—With such a palpable hint, I should suppose that surgeons would banish forever their salves and ointments in curing wounds, and suffer them to be healed by nature's own process. It would be a marvellous cure indeed if a surgeon could heal up a long, gaping wound in twenty nine hours, as nicely as if nothing had ever happened.

Dr. B.—John Hunter first clearly understood this process, towards the latter part of the last century, and made it the basis of one of the greatest improvements that have been made in Surgery. Before his time, surgeons were generally accustomed to stuff a wound full of lint, and balsams, and salves, and thus the simplest wounds were weeks and even months in healing. Now they endeavor always to bring the sides of the wound in contact, and retain it there without any other applications. To see to what extent this union between divided parts might be carried, Mr. Hunter cut off the spur from a cock's foot, and making a slight incision into the comb, he placed the spur into the wound and bound it

up. The result was, that they united, and the spur continued to grow on the comb full as well as it had done in its natural position. The same effect took place, when he removed a tooth from a man, and engrafted it on a cock's comb. Fingers, after having been completely chopped off, have been bound to the stumps and become perfectly united to them. In cases of wounds where there is a deficiency of substance, surgeons have lately adopted the practice of supplying the deficiency by strips of flesh removed from other parts of the body. In the East Indies where it is the practice of the chiefs to cut off the noses of their prisoners, the operation is frequently practised of making a new nose, out of a strip of flesh that is cut from the forehead, but still adhering by one extremity, and made to unite with the stump of the absent member.

Emily.—I think I have heard of this operation before, but always supposed it was merely an idle tale. But pray Dr. B. what kind of a figure does the new nasal member make in the man's countenance?

Dr. B.—It is said that some very handsome noses have been made in this way. You must admit that there is certainly one advantage gained by having a nose thus made to order;—you can consult your own taste about its shape as you would the cut of your coat, and have it Grecian, or Roman, or in any other style, according to the fashion which happens to be in vogue, or as it harmonizes with the other features.—This closes the history of the Circulation. In our next conversation we shall examine the organs and functions of respiration.

CONVERSATION V.

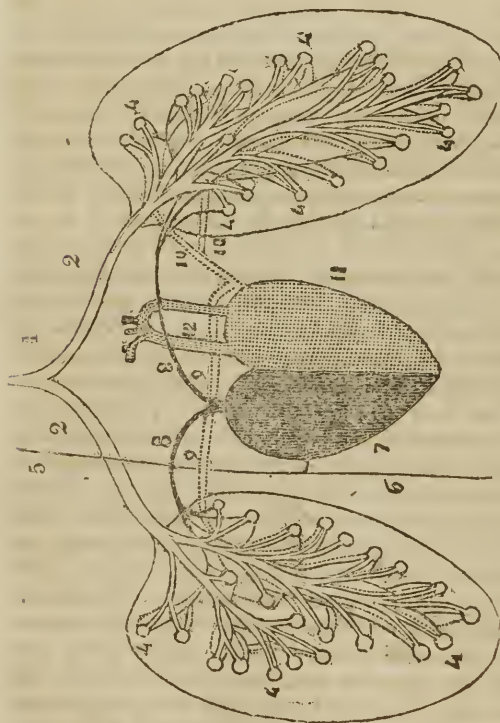
Respiration—the lungs—the thorax—mechanism of inspiration—changes wrought on the air by respiration—relation of these changes to those wrought on the blood—animal heat—respiration of Fishes—of Birds—of Reptiles—of Mollusca and Insects—of Spiders.—Secretion—various kinds of Secretions—Secretion in the inferior animals.—Absorbtion—performed chiefly by the veins—the lymphatics—the lymph.—Nutrition.

Dr. B. To day we are to consider the changes which the blood undergoes in its passage through the lungs, and the mechanism of the parts concerned in producing them. The respiratory organs are two light, spongy, and rather irregularly shaped bodies, placed in the *thorax*, or chest, one on each side, called the *Lungs*.—They are composed almost entirely of air-cells and blood vessels, though some other tissue is probably present, which serves as a common bond of union. These little air-cells, which are of extreme minuteness, are distributed to every portion of the organ, and seem to be the ultimate ramifications of two large tubes, which lead, one to each lung, called the *bronchiae*. The blood vessels belong to the capillary system, and communicate with the pulmonary arteries and veins. They are situated in the tissue of the cells, and it is while the blood is passing through them, that it is subjected to the respiratory process. The bronchiae are the subdivisions of a single tube, called the *trachea*, or windpipe,

which is situated in the neck, directly over the œsophagus, and communicates with the mouth by an opening, which, you will recollect, we have already noticed.

Emily.—The chink of the glottis—one of the seven openings into the pharynx ; I recollect it.

Dr. B.—The air-tubes, and perhaps the air-cells, are lined with mucous membrane similar to that which lines the alimentary canal. In this engraving you have a di-



In this diagram the *dotted* lines represent the course of the arterial blood ; the black lines, of the venous blood ; the spaces bounded by black lines represent the distribution of the air-tubes.
 1. Trachea. 2 2. The bronchiæ 4 4 4. The air-cells. 5. Great Descending Vein 6. Great Ascending Vein. 7. Venous side of the heart 8 8. Pulmonary arteries. 9. Pulmonary veins of the right side. 10. Pulmonary veins of the left side. 11. Arterial side of the heart. 12. Aorta, sending the blood to all parts of the body.

agram of the lungs, and the bronchiæ leading into them, together with the distribution and re-union of the vessels.

They are covered externally by a smooth, shining membrane called the *pleura*—the same kind of membrane, that lines the walls of the chest and abdomen, and forms the external coat of the alimentary canal. While in action, they completely fill the cavity of the chest, that is not occupied by other organs, so that no empty space is ever left.

Emily.—What an admirable system of machinery is here! I never imagined however, that the lungs were sufficiently large to fill almost the whole cavity of the chest.

Dr. B.—To understand how the air gets admittance into the lungs, we must first examine the structure and mechanism of the chest. Its form is conoidal, the apex being at the top, and the base at the bottom. Behind, it is bounded by the spine; at the sides, by the ribs; in front, by the *sternum* or breast bone; below, by a thin membranous muscle, called the *diaphragm* or midriff, which forms the floor of its base, and separates it from the cavity of the abdomen. These parts are joined together in such a manner, that considerable motion is allowed between them, and by this means the capacity of the chest may be considerably enlarged and diminished. The depression of the diaphragm enlarges the chest at the expense of the abdomen, while the ribs being thrust forward and upward by means of the numerous muscles, that are attached to them, produce an enlargement in the other directions. The lungs follow the variations of capacity in the chest, expanding their air-cells, when the latter is enlarged, so as still to fill up the whole cavity, and collapsing, when the chest is contracting. Now observe how they become filled with air. Suppose that expiration has just taken place, the lungs in a collapsed state, and the chest reduced to its smallest capacity. This state of things can last but a few moments. The necessity of fresh air is felt, and we instinctively expand the chest. The lungs follow the expanding walls of the chest, and consequently a vacuum is produced in their

cells. The external air, with which they freely communicate, accordingly rushes in through the mouth and nostrils, and fills the vacuum as fast as it is made.

Emily.—But I had always supposed that the chest and lungs expanded, *in consequence* of the admission of the air.

Dr. B.—To be convinced that you are wrong, you have only to open your mouth and nostrils as wide as you please, and see if the air ever rushes in, till by a voluntary effort, you begin to expand the chest. A person would breathe equally as well, if the mouth and nostrils were closed, and an opening made in the wind-pipe. When the chest contracts, the air is consequently expelled, and thus are produced, in constant succession, the two acts of inspiration and expiration.

Emily.—According to this then, these acts are altogether involuntary, and yet you know we can delay either of them a few moments, and I have heard of people, whose business is to dive for pearls, who could remain under water a half hour at a time. These facts prove at least, that the function is in some measure under the will.

Dr. B.—These cases are, in all probability, great exaggerations, though people can, no doubt, by education extend the influence of the will over this function to a certain extent, in the same manner as we can accustom our constitution to a less quantity of food or exercise. Still the action is strictly involuntary—try as hard as you may, to suspend the act of inspiration, the muscles will invariably contract and expand the chest, in spite of your exertions.

Emily.—Supposing now the air to have penetrated into the cells of the lungs—I cannot imagine how it is to affect the blood. In the first place, however, I should more properly ask, what changes in the blood it does produce.

Dr. B.—The blood conveyed to the lungs, is from a modena red converted into a bright scarlet color ; its

odour is more pungent ; its temperature is from 98° of Far. raised to 100° ; its capacity for caloric is a little lessened ; it coagulates more quickly, and is less abundant in serum.

Emily.—Now I may ask how these changes are produced ?

Dr. B.—And truly a question more easily asked than answered. But at any rate we can tell pretty exactly, what changes the air itself has undergone, and if it were true, as was once said by royal lips, that “in a multitude of counsellors there is wisdom,” we might be exceedingly wise concerning the changes that are produced in the blood. The air, which we breathe, is composed, you know, of two gases, *oxygen* and *nitrogen*—21 parts of the former, and about 78 of the latter. Besides these, there is generally found a very small portion of carbonic acid—about 1 part. Such is the composition of the air when it goes into the lungs, but not such when it comes out. If we examine a quantity of expired air, we shall find that the *oxygen*, instead of forming 21 parts of it, now forms only 18 or 19 parts, that the carbonic acid amounts to 3 or 4 parts, and that the nitrogen is not apparently increased or diminished. So you see that *oxygen* alone is made use of in the performance of this function ; and the rapidity with which its deprivation causes the death of any living being, well entitles it to be considered as the grand supporter of living action.

Emily.—Since the *nitrogen* is returned unchanged in quantity, what can possibly be its use in respiration ? Would not an air of pure *oxygen* answer the purpose just as well ?

Dr. B.—Though we are unable to see what part the *nitrogen* takes in the process, numerous experiments prove that it is not useless, nor to be dispensed with ; for though an animal will live four times longer in pure oxygen, than in the same quantity of atmospheric air, yet when breathed for any length of time, the organs

become stimulated beyond measure, and death is the consequence.

What the chemical changes are, which respiration produces in the blood—what it receives and loses, are points which have occupied considerable attention from chemists and physiologists, and given rise to experiments, whose results are any thing but harmonious. To account for the carbonic acid in the expired air, some say that carbon is *secreted* from the venous blood, into the air-cells of the lungs, and there unites with the *oxygen*, forming carbonic acid. They say that the only use of the *oxygen*, is to decarbonise the venous blood, and that no more oxygen is consumed, than is necessary for this purpose; that no oxygen enters into the arterial blood, but its florid hue is the result of its loss of carbon. The promulgator of this doctrine was Mr. Ellis, of Edinburgh, and he applied it to the respiration of plants. His experiments are numerous, and *seem* quite satisfactory. Others say, that oxygen *does* enter the blood, and that it is the chief object of respiration, to supply the blood with this vivifying substance. The carbonic acid in the expired air, they say, is secreted from the venous blood. This was the theory of Lavoiser, the celebrated French chemist. The experiments of Dr. Edwards, of Paris, prove that carbonic acid is formed in the blood vessels, because the same quantity of carbonic acid is given out when the animal breathes hydrogen gas, as when he breathes atmospheric air. It seems probable too, that some of the carbonic acid is formed in the way which Mr. Ellis supposes. *Oxygen* is of course absorbed, and while circulating in the vessels, it probably unites with the carbon, and forms the carbonic acid, that is secreted, though this is not the only source of this gas.

Emily.—But now I do not understand any better, how the changes in the air produce the changes in the blood, which you mentioned. I see no manner of connection between these two sets of facts.

Dr. B.—About all the physical changes produced in the blood by respiration can be more satisfactorily explained by admitting the presence of oxygen, than merely a loss of carbon. The fact then that they are owing to a fresh supply of oxygen is nearly all we know of it; how it should have this effect, we cannot explain.

Emily.—That carbon in some form or other is emitted from the blood in respiration, is one fact at least in which they all agree. The *decarbonization* of the blood then, is one object of the function, whether its *oxygenation* be another or not; but I do not understand where all this carbon comes from.

Dr. B.—You must recollect that it is into veins that the nutritious aliment prepared by digestion, is poured, as well as a considerable portion of those particles of the body that have become unfit for nutrition and require to be removed from the system. These materials all abound with carbon, and it is from this source that the carbon in the venous blood is derived.

Emily.—It has just occurred to me, Dr. B., that if these chemical changes are actually going on in the lungs, they ought to be accompanied with their usual results. The union of carbon with oxygen, so as to form carbonic acid gas, is attended with a disengagement of heat, as any one may know who ever sat by a charcoal fire.

Dr. B.—And so you would expect that the lungs, not being made of exactly fire-proof materials, must inevitably get scorched?

Emily.—Rather an unpleasant conclusion indeed, but really, I see not how it can be avoided.

Dr. B.—No sooner were the chemical changes that are effected in the lungs, brought to light, than physiologists began to connect the production of animal heat with the function of respiration. At first it was imagined that the lungs themselves were the grand furnace in which the caloric was manufactured, that was to be taken up by the blood vessels and carried to every portion of the sys-

tem. Finding afterwards that the consequences which you suggested rendered this theory untenable, they concluded at last that the oxygen was absorbed into the vessels, and that its combination with carbon, and the consequent disengagement of heat, took place gradually throughout the whole venous system. Thus a constant and equal warmth is diffused over the whole body.

Emily.—What a beautiful theory! How admirably the greatest results are sometimes effected by apparently the most ordinary agents.

Dr. B.—Beautiful indeed it is; but unhappily we cannot speak so favorably of its truth. The venous blood in which the carbonic acid is supposed to be formed, instead of indicating a higher temperature than the arterial blood, as it evidently ought, is even two or three degrees lower. This, together with many other facts which have been established by later experiments, have now pretty generally discredited the theory, and Physiologists have been obliged to turn their attention to some other source for an explanation of the effect in question.

Emily.—If the same theory was expected to apply to the respiration of plants, it must inevitably have been falsified there. Plants have a temperature above that of the atmosphere in the middle of winter. I have often observed that the snow which falls on their limbs and around their roots, soon melts away, and *Dr. S.* mentioned last summer in his botanical lectures, that if the bulb of a thermometer be introduced into the trunk of a tree in the coldest day, the mercury will rise above the freezing point. At this time their branches are destitute of foliage and no respiration can consequently be going on.

Dr. B.—We are not positive that vegetable heat and animal heat are both produced in the same way; but still if you had been sufficiently acquainted with the subject, you might have adduced analogies from the animal kingdom, equally conclusive. Many reptiles lie in

a torpid state for months together, when the function of respiration is wholly suspended, and still their temperature is above that of the surrounding medium. Some late experiments of Mr. Brodie seem to show that the production of animal heat is entirely independent of respiration. He inflated the lungs of an animal after death and maintained an artificial respiration. The usual changes continued to be wrought on the blood; it was converted from its modena hue to bright scarlet, and carbonic acid was formed, but the body lost its heat as fast as if it had been suffered to remain at rest.

Emily.—But, Dr. B., are we to give up the point in despair and consider it wholly beyond our power of explanation?

Dr. B.—It has been lately suggested that it might be the result of a peculiar action of the nervous system on the capillary vessels; but no attempt having been made to establish it by a systematic array of proofs and arguments, it is as yet merely a suggestion.

Emily.—If you had not objected to my analogy drawn from the vegetable kingdom, I should say that this theory was equally unsupported by it, for I never as yet heard that plants possess a nervous system.

Dr. B.—They have not a nervous *system* it is true, but for any thing we know, particles of nervous matter may be diffused through their structure, and capable of producing the same effects in regard to vegetable heat, that a proper nervous system does in regard to animal heat. But although we are unable to explain the cause of this phenomena, the facts connected with it are no less certain, or interesting. Some of them are as curious as they are inexplicable, particularly the power of organized bodies to preserve a uniform temperature notwithstanding the changes in the surrounding medium. Thus the temperature of the human body is between 98° and 99° of Far. whether we examine it in the Esquimaux who dwells in his icy hut under the polar circle, or the Negro who feels the scorching rays of an equatorial sun.

Emily.—But would not their temperature change, if each were removed to the country of the other? Place the Esquimaux in the torrid zone, and I think he would feel a little warmer, and even you or I would, though the transition would be much less.

Dr. B.—Of course, then, if you would be consistent, you suppose that our temperature is greater in summer than in winter. No; the temperature of the body remains the same through all the seasons. Our feelings are no test of the temperature as indicated by a thermometer. Even in the midst of a raging fever, when the person *feels* as if he were actually burning up, the thermometer will often indicate a degree of heat, a little less than that of ordinary health; while in the cold paroxysms, when he is shivering from head to foot, it may indicate a degree or two more. It is astonishing to see how great a degree of heat the body will stand, and still retain its natural temperature. Under the observation of the Academy of Science, in France, two girls entered an oven where fruits were baking, and stayed there several minutes, without suffering any ill effect. Reaumur's thermometer, which they carried with them in their hands, stood at 150° , equal to $337\frac{1}{2}$ of Far.

Emily.—The story of Sir Joseph Banks, Dr. For-dyce, and Dr. Blagden's attempting to ascertain how high a degree of heat the system could withstand, is also very interesting. A suit of three rooms heated by flues in the floor, was prepared, into which they entered, without taking off their clothes. When they first entered, the mercury in Far. stood at 150° , and they continued 20 minutes; during which time, the mercury rose 12° higher. At another time, the mercury stood at 198° , and they continued in this heat 10 minutes.—In a heat of 211° at first, Sir J. Banks remained 7 minutes; in which time the mercury sunk to 198° . All this time, the temperature of their bodies rose very little above its ordinary state. Whenever they breathed on the thermometer, the mercury sunk several degrees;

every expiration afforded a pleasant, cooling impression to the nostrils, and their breath cooled their fingers. Dr. Blagden, on touching his side, found it felt like a corpse. Their watch chains, and pièces of metal, which they had in their pockets, were so hot that they could scarcely touch them. In subsequent experiments, the heat of the room was 240° , and even 260° . These excessive degrees of heat they bore without experiencing any injurious effects. The circulation was raised to 140° in a minute, and their perspiration was extremely copious, running down in streams over their bodies. I do not recollect all the details of the account, but these are the principal facts.

Dr. B.—Before we quit this subject, we shall find it interesting to look a moment or two, at the various modes, in which the respiratory function is managed in the lower orders of animals.

Emily.—I am glad you have proposed this, for I never could conceive how this function is managed in fishes, for they surely have no access to the air. But first let me ask if the human constitution manifests a similar power of preserving its own temperature, in exposures to extreme cold, as well as heat?

Dr. B.—Its power in this respect is no less wonderful than in the other; some astonishing instances of it have been from time to time recorded by voyagers and travellers. Lewis and Clarke relate that two Indians, a man and a boy, slept on the snow in an ordinary light dress when the mercury in the thermometer, at sunrise, was 40° below zero. The man suffered no inconvenience; the boy had his feet frozen, but they were recovered by cold water.

Emily.—I recollect a striking fact of this nature recorded by Capt. Lyon, in the Journal of his voyage to the polar regions. He says that he often saw the young Esquimaux children exposed half naked to the open air, when the mercury was 32° below zero; and that too, without suffering any apparent inconvenience.

Dr. B.—And how much more astonishing it is that Europeans who have been accustomed to warmer climates, should be able by using the proper precautions, to bear such severe cold, with equal impunity. The English, at one of their trading houses on the Churchill river, experienced, one year, such a degree of cold that brandy froze in the rooms where they had fires.

Emily.—Ledyard, I recollect, experienced in Yakutsk, Siberia, a degree of cold which coagulated strong coguiac brandy.

Dr. B.—Many more observations of a similar kind might be mentioned, but these are sufficient to show how independent of external changes, is the temperature of our bodies.

I will now describe to you how the function of respiration is managed in fishes. They cannot obtain access to the atmosphere, it is true, but there is always a quantity of air mixed with the water in which they live, and they are furnished with organs fitted for separating it and applying it to the same purpose as the lungs of animals. Instead of lungs in the interior of their body, they are provided on each side of the neck with several thin, red laminae of a semi-circular form, called *branchiae* or *gills*. These are attached to the bones and covered with a movable lid. In these gills are ramified the extremities of the pulmonary arteries and veins, and also the capillary vessels in which the necessary changes are wrought on the blood.

Emily.—I have heard that if fishes were kept in close vessels, and communication with the atmosphere cut off they would soon die, but never knew before that it was for lack of air; for I suppose their death is produced in consequence of all the air in the water being consumed. But is it not strange that they should die so soon when taken out of the water, merely because they breathe pure air, and not air in combination with water?

Dr. B.—This is sufficient to produce their death, for their respiratory organs are constructed for breathing air

only in the manner in which they do. But this is not the only cause, since if a fish have his head and gills immersed in water, and the rest of his body exposed to the atmosphere, he will not live but a few days. Death seems to be occasioned by an excessive loss of matter by transpiration from the exposed surface of the body, and to a change in the pressure of the surrounding medium, as well as to the unfitness of the gills to act upon the atmosphere.

Emily.—Do tell me, Dr. B., why fishes are called *cold-blooded* animals? They no doubt have a certain temperature which is unaffected by external changes.

Dr. B.—They are called cold-blooded because their temperature is very low compared with ours, though it is generally a little above that of their usual medium. The standard heat of fresh water fishes is 60° ; that of those of the sea, about 50° . What is exceedingly singular in regard to the animal heat of fishes, is that it is considerably modified by external temperature. Mr. Hunter put an eel whose heat was 44° , while that of the atmosphere was the same, into water heated to 65° for fifteen minutes; upon examination at the end of that period, it was found to be of the same degree of heat with the water. Having put an eel, the heat in whose stomach was 37° , into a freezing mixture, its temperature sunk to 31° . The animal at that time appeared dead, but next day it was alive. At another time he put a living and dead eel and a living and dead tench—a fish not found in our waters; it belongs to the same family with the carp—into warm water; they all received heat equally quick, and when they were exposed to cold, both the living and dead lost their heat with equal quickness. It is strange too, to see in what a hot medium fishes sometimes live. Sonnerat declares that he saw in the Philippine islands, fishes swimming in water whose heat was 187° of Far.

Emily.—Why, an access of a few more degrees of

heat would boil them alive. I presume they are cautious how they take exercise in such a torrifying medium.

Dr. B.—The respiration and circulation of birds are upon the same plan as those of man and the large quadrupeds. These functions possess a higher degree of activity than in the last animals, and in fact may be considered as at their maximum in the Bird. Birds have no diaphragm; the lungs adhere to the ribs and extend far down into the abdomen; and the chest does not change its capacity in respiration. The air is admitted into and expelled from the lungs solely by their own force. Their animal heat is also greater than that of any other animals, and may be stated as varying from 104° to 107° of Far.

From a few experiments that have been made, it appears that birds are less capable of resisting the extremes of heat and cold, than other animals. The migrations of birds are evidently for no other purpose than to avoid those extremes of temperature incident to many regions. The swallows are unable to bear the cold of the New England September, and a little premature cold weather, hastens their departure several days, if not weeks. Of all the birds that enliven our fields in summer, not one remains to share with us the rigors of the cold and dreary season. Even the little snow-bird which forms such a lively feature in our winter scenery, has come from higher and colder regions, to enjoy a more genial climate in ours.

Emily.—I used frequently to see them in the country, and though they seemed gay and active, as they flew along from one field to another, yet I pitied them, for I thought such tender things must suffer from the cold.

Dr. B.—The respiratory organs of reptiles, though formed for breathing atmospheric air, are less perfect in their organization than the lungs of other animals. Instead of consisting of solid fleshy organs, penetrated throughout with innumerable air-tubes, they are composed of numerous delicate membranous bags, communi-

eating together, and occupying considerable space on the sides of the body. The air is swallowed through the nostrils by a peculiar working of the jaws, and is expelled by the action of the abdominal muscles. This sort of lungs is capable of acting on but a comparatively small portion of blood, and now if we look at the circulation of these creatures, we shall see how admirably these two functions, respiration and circulation, correspond to each other.

The circulation of Reptiles has this peculiarity which distinguishes it from that of all other classes—the blood which is brought from both the body and the lungs, is poured into a single reservoir, or into two or three, which finally communicate, where it is mingled together, and thence sent back again to the lungs and body.

Emily.—Then some portion of the blood sent away to nourish the body, is venous, and some of that sent to the lungs to be renovated by their action, is arterial, and of course does not need their action. Why, what can be the reason of this? I should think they would suffer the fate of the *blue-boys*, whom you spoke of yesterday.

Dr. B.—The nature of their lungs is such, that they are unfitted for acting on blood which is wholly venous; it would require a greater amount of action than they are capable of. So too, if the arteries carried only arterial blood to the body, it would be renovated and excited beyond its proper measure.

Emily.—Still, I do not understand clearly, why this inactivity of respiration and circulation, should be so particularly necessary to Reptiles, or, to use the language of writers on natural theology, I do not perceive the *final cause*.

Dr. B.—This is not very obvious, though generally it does appear very clearly to depend on their habits of life. Most of them live in the water, and are obliged to remain under the water for very long periods before coming up to breathe; an active respiration, like man's or the birds', would obviously be incompatible with such a mode

of life. Others live in confined and dirty places, where they are obliged to breathe foul and noxious gases, which would suffocate animals of more active respiration. It is curious to see how long they can live when utterly deprived of air. Turtles have been known to live a month and more, with their jaws tied closely together and stopped up with sealing-wax. Dr. Edwards completely cut out the lungs from two frogs, and found that one lived 33 and the other 40 days, in wet sand.

Emily.—I have read of toads being found alive, completely immured in solid rocks, or in the heart of trees. My faith has been always staggered by such stories, but, I suppose now there is some foundation for them in truth.

Dr. B.—It is probable that in all these cases, the animals were either in a torpid condition, or that they had communication with the air by means of some hole or fissure in the rock.

In the *Mollusca* or shell-fishes, we find considerable variety in the construction of the respiratory organs. In those which live on the land, and those which are obliged to come to the surface of the water to breathe the air, we observe a lung which differs from other lungs, by consisting of a single membranous bag, communicating externally by a narrow aperture which can be closed or opened at the will of the animal, while the bag contracting and dilating, expels or admits the air. On the sides of this cavity are ramified an almost infinite net-work of blood-vessels, containing the blood which is to be renovated by the influence of the air. In other species, we observe gills projecting externally, and sometimes resembling tufts of branches, forming a kind of hedge all around the body. In others, the gills are contained in the mantle which surrounds their body, and the water is admitted and expelled by the successive contraction and dilatation of this mantle.

The heat of the *Mollusca* is very nearly the same as that of the surrounding medium; in the snails it is a few degrees above. Mr. Hunter found the lungs of a snail

to be 38° , when the atmosphere was 34° ; and in several instances, when the temperature of the air was 30° , that of the snails was considerably above— 6 or 7° .

In *Insects*, respiration is managed differently from what it is in either of the classes I have already named. They have neither lungs nor gills, but are furnished with minute organs, called by naturalists *stigmata*, which are a number of small tubercles, ranged along each side of the body, each having an aperture at the top, called the *spiracle*, through which the air enters. These *stigmata* are situated on the sides of the back, and lead into true air-tubes, which branch off in every direction, supplying all the parts of the body and members with air. That these are respiratory organs, there can be no doubt, for if they be covered up with oil, respiration ceases, and the insect dies. If they be stopped up on one side only, the vital functions of that side are impeded, and the members are paralyzed.

Emily.—A curious kind of respiration surely; and a curious kind of circulation it must be to correspond with it; for I have not the slightest conception how it is constructed.

Dr. B.—A true circulation never has been discovered in perfect insects. The blood is collected into one large vessel situated in the back, but no vessels have been observed branching off from it. The air-tubes seem to serve the office of blood-vessels, and present a singular contrast to those of the higher animals. In them the blood is carried to the air; in the insects, the air is carried to the blood—or as Cuvier beautifully expresses it, “the air goes in search of the blood.”

The respiratory organs of some *larvæ* of insects, though they live in water, are fitted for breathing only air. They are situated in one extremity of the creature in a tail-like appendage which they always contrive to keep above the surface, for if plunged entirely beneath, they appear restless and agitated, making frequent attempts to rise again to the air. Some of them

are capable of extending their tails to a considerable degree, so that they can keep them above the surface without always changing their positions with every change in the level of the water. Reaumer desirous of seeing how far they could thus extend themselves, began to add water slowly till he had raised it six inches; the larvæ in the mean time continued to lengthen themselves until they reached this height, when they were forced to change their position and attach themselves high up on the sides of the vessel.

Spiders breathe by means of eight or ten stigmata which lead into a sac, on the sides of which are situated little laminae or fringes, in which the blood circulates that is to be renewed by the air.

Leeches and earth-worms have no other apparatus for breathing but the skin, in the vessels of which the blood is aerated.

Emily.—What wonderful diversity in the construction and arrangement of organs, whose ultimate purpose is the same! And how perfectly does every change harmonize with other co-existing modifications!

Dr. B.—Having finished the subject of respiration, we will turn our attention to the function of *secretion*.

Emily.—Secretion means *separation*; I had no idea that there was any such function as this in the animal economy.

Dr. B.—All the fluids in the animal body are derived from the blood, and the process by which they are separated from the blood is called *secretion*. But you are not to suppose that all these fluids existed already formed in the blood, and that the only object of secretion is to separate them therefrom; for some of them—in deed most of them—are formed by the secretory organs from materials which exist uncombined with the blood.

Emily.—This process approaches the operations of chemistry nearer than any other which we have yet attended to.

Dr. B.—And yet it is no easier to explain it on any chemical principles, with which we are acquainted, than the other functions of life. They all indeed are governed by laws *apparently* chemical, and to such a degree as to justify the language of a very distinguished French physician, who has styled them a “vital chemistry.” Of the precise manner in which this function is performed we are totally ignorant.

Emily.—But what is the nature of the secretory organs? Cannot we obtain some light from this source?

Dr. B.—Not the least. We here feel the full force of a truth recognized by anatomists, that the most perfect knowledge of the structure of a part does not necessarily lead us to a knowledge of its function. The organs of secretion are so varied in their form and structure, that it is difficult to exhibit a correct general view of them, and an idea of their details can be obtained only by personal examination. They are called *glands*; they vary in size from that of a pin’s head to the magnitude of the largest organs in the body and are generally of a rounded shape. They consist of a multitude of minute arteries and veins connected by means of cellular substance. The fluid which is secreted from the blood in these vessels, is either taken up and carried away to fulfil its destined purpose, by other vessels, or more properly *ducts*; or the fluid is poured out directly as fast as it is secreted, on the surface of the parts where the glands are placed, without the intervention of any duct. To obtain a clearer idea of the secretions, we will distinguish them into the five following classes, viz: the *aqueous*, the *serous*, the *mucous*, the *oleaginous*, and the *resinous*.

Emily.—And all these are derived from one and the same source—the blood. What an immense storehouse of heterogeneous materials, this fluid must be!

Dr. B.—We have not time to say much about them, and therefore, shall barely say enough to give you some idea of their nature and use. The *aqueous* consists al-

most wholly of water. The principal one of them is the matter of perspiration secreted from the skin, and though almost entirely composed of water, its expulsion from the system is absolutely necessary to a state of good health. Its quantity is so small that it is always imperceptible to the eye, unless it be increased by an unusual warmth of the body. Then it collects in large drops on the skin, and is popularly called *sweat*. It has been ascertained from experiment, that the whole quantity of insensible perspiration, including that from the lungs, varies from eleven to thirty-two grains in a minute.

Emily.—I never knew before, that the lungs perspired; pray how is that fact ascertained?

Dr. B.—You have only to look at a person in a cold day, when he is pouring out from mouth and nose successive jets of warm vapour, which is condensed by the cold air, to satisfy yourself of the fact; or to save the trouble of going out on purpose, just breathe a few times on the mirror, and see the matter of perspiration condensed on its cold surface.

Emily.—I have observed all this, but I never imagined it came from the lungs.

Dr. B.—A curious fact in the animal economy is, the nice sympathy which exists between the lungs and the skin. Hence, in a climate where the temperature is constantly undergoing great and sudden changes, you see a fruitful source of disease. The perspiration of the skin is frequently checked—the irritation is propagated by sympathy to the lungs—these delicate organs are stimulated beyond their natural measure by the increased action to which they are thus subjected—frequent repetition of this undue excitement leads to inflammation and change of structure—and consumption is the common termination of the scene.

The *serous* secretions do not differ materially from the serum of the blood, and are poured out over the whole surface of the *serous membranes*. These membranes line the cavities of the body which have no com-

munication with the atmosphere, such as the abdomen, thorax, pericardium, pleura, &c., and are reflected over the organs which lie in these cavities. The principal use of these secretions is, to furnish these parts with a proper degree of moisture, so that they may glide freely and smoothly over one another. In diseased states of the body, these secretions sometimes accunilate to a prodigious extent, constituting the disease of *dropsy*.

The *mucous* secretions are a transparent viscid fluid, of a saltish taste, consisting of water and a very small portion of several alkaline and earthy salts. It is poured out from the surface of those membranes which line cavities of the body that have an external communication, as the alimentary canal, air-passages, &c., serving to protect these parts from the atmosphere, and concurring by means of its peculiar properties, in the performance of their functions. It is formed by minute bodies of a glandular character, immediately below the membrane called *mucous cryptæ*; sometimes however, it is secreted from glands of a considerable size, as the *parotid* and *salivary* glands in the mouth, which secrete the saliva.

Of the *oleaginous*, the principal is the fat which is found in different parts of the body, and always secreted from the cellular tissue. Its chief use seems to be the protection that it gives to the parts where it exists, against the pressure of foreign bodies, as in the sole of the foot for instance, and to give a general rotundity of outline to the surface. In some cases, as in corpulency, it accumulates without answering any particular purpose; here the object of the secretion seems to be merely to free the blood from its superfluous carbon and hydrogen. The milk of animals belongs to this class of secretions.

The resinous secretions consist of substances very remote from any thing we find in the blood. The principal of them is the bile which has been already described. It is called a resinous secretion, because it contains a

peculiar substance, called *picromel*, or the resin of the bile.

Emily.—Does this function in the inferior animals vary as much as respiration, circulation, &c.? I hope you will not confine your view of it to man alone, for to me the history of the vital functions as they exist in the inferior animals, is no less interesting.

Dr. B.—The function is probably performed in the same way in them that it is in man; its products however are varied almost to infinity. As it would be foreign to our purpose to take them up in detail, we must be content with looking only at a few of the most important and curious. A singular product of secretion in the mammiferous class, are the horns of the ruminating animals. In the winter or spring season, an unusual quantity of blood is determined to the head, a membrane is formed on the skull containing numerous vessels, bony matter is secreted from them, and the membrane extends until the whole horn is produced. In some families this process is performed annually—the horns being shed once a year.

The venom of serpents is also a product of secretion. The venomous serpents are provided with a couple of long fangs, which they have the power of erecting and depressing at will. At the bottom of the fang is a little gland that secretes the poison, and a canal in the middle of the fang gives issue to the venom when required. The shells of the shell-fishes—those beautiful shells whose brilliant and variegated colors you have so often admired, are secreted from the membrane that forms the envelope of the animal. What is still more strange, those branches of coral, sea-fans which you have frequently seen, are secreted by animals of microscopical dimensions.

Emily.—Indeed. Dr. B., I have been told that the coral itself is of an animal nature, and have been rallied not a little for expressing my incredulity about the fact, for it always appeared to be nothing but limestone.

Dr. B.—You have either been misinformed, or have misunderstood your informants. The coral is the produce of animals of the Zoophyte class, and is raised for the purpose of serving as an abode for myriads of these minute creatures who extend their feelers through the apertures which you may observe on the surface. So numerous are these beings and so rapidly do they carry on the construction of their habitations, that whole mountains of coral are sometimes formed under the sea, encircling islands and coasts, and filling the path of the navigator with unknown perils. Some of the islands in the Pacific ocean are formed entirely in this way.

Emily.—Well, this is the most astonishing of all; whole islands the produce of secretion! and that too, of creatures which are hardly perceptible to the naked eye! I thought you had already mentioned some most wonderful facts, but really this surpasses them all.

Dr. B.—Perhaps you would be equally surprised if I should tell you that the very garment which you wear, is the product of secretion; and yet such is the case.

Emily.—Do explain yourself, Dr. B., unless you are really jesting I do not understand it. This silk frock of mine, I had always imagined, was woven in looms in foreign countries; can it be this you refer to?

Dr. B.—Right; but the silk itself once constituted the *cocoon* or habitation of an insect, which it made for itself to pass away the period in, which intervenes during its change from the larva to the perfect state. It is spun by the silk-worm, from materials that are abundantly furnished by certain secretory organs, expressly destined for this purpose, and afterwards is woven by manufacturers into a stuff which has become indispensable in all civilized countries. This must finish the subject of *secretion*, and if you are not wearied we will proceed to examine another of the functions of life.

Emily.—Have no concern on that score. But pray, what may be the next subject that will require our attention?

Dr. B.—We are now to consider a very important, though rather obscure function—that of absorption, by which different substances, within or without the body, are taken into the circulation, and appropriated to various purposes. This function is very manifest on the skin, though not so active here as in some other parts. Thus, if mercurial ointment be rubbed on but a small portion of the surface, for a sufficient length of time, it will finally affect the whole constitution. It is by absorption that the poisonous matter of contagious diseases, such as small pox, measles, &c. is admitted into the system and produces a similar affection.

Emily.—The poison of the venomous serpents, I suppose, is introduced into the circulation in the same way.

Dr. B.—Not precisely the same; it is absorbed by the skin indeed, but it is necessary that the surface should be broken, as it is by the tooth of the animal,—merely rubbing it on the sound skin would produce no injurious effects. I suppose now you see at once the utility of applying cupping-glasses, over the wound and ligatures above it, as well as the practice sometimes observed of sucking the wound with the mouth.

Emily.—I should think that the circulation in the part being partially stopped by these means, the absorption of the morbid matter is checked, and extracted from it by the latter method. But is it not liable to be absorbed from the mouth of the person who sucks the wound?

Dr. B.—Not if the surface of the living membrane be sound.

Emily.—Still is there no danger of swallowing some of it along with our saliva? I am sure I never should dare to do it, from this apprehension.

Dr. B.—The lining membrane of the stomach you know, is merely a continuation of that in the mouth, and swallowing the poisonous matter would be equally harmless with holding it in the mouth. The poison of vipers has been swallowed without giving rise to any un-

pleasant effects, and in our new settlements, swine are said to devour rattlesnakes, and with a high relish too for the choice morsel. But absorption not only takes up foreign substances, but is in incessant action in every part of the system, removing particles of matter that are no longer fit for the purposes of the vital economy, and whose places are supplied by fresh materials, as well as others that have accumulated in particular parts, as a consequence of injury or disease. Thus the *mucous* and *serous* secretions are constantly absorbed just as fast as they are secreted. If this were not so, they would accumulate and become a source of disease. In bruises and swellings where blood or the serous portion of it is effused, no cure can take place until these fluids are removed, and absorption is the agent by which this is effected.

Emily.—I have often wondered what becomes of the blood which is poured out when a bone is broken or a severe bruise received, for I never observed that in such cases, the physician used any means to take it away.

Dr. B.—It is because he is acquainted with this power of the animal economy, and knows that it is better to forbear offering his assistance. You may set this down as a general law of the animal economy, that when the good condition of the system no longer requires the presence of any part, it is removed forthwith by the powers of absorption; provided that the constitution enjoys at the time a sufficient degree of health to accomplish this process.

Emily.—I believe you have not yet mentioned the organs by which this function is performed, and I have just thought of asking the question.

Dr. B.—This has lately been made a subject of considerable discussion, and opinions are not yet settled concerning it. According to the old theory, the function of absorption is performed by a set of vessels very similar to that by which the chyle is absorbed from the alimentary canal. The *lymphatic* vessels, as they are

called, exist in every portion of the body ; like the veins, they diminish in number as they increase in size, while pursuing their course towards the veins of the arms into which they pour their contents. In their course they frequently traverse the *lymphatic glands*, which are to these vessels what the *mesenteric glands* are to the lacteals. They are situated chiefly in the groin, arm-pits, and neck, in which latter place they are frequently swollen in consequence of cold.

Emily.—What is the nature of the fluids contained in the lymphatic vessels? I suppose however, since they are the general reservoir of all the waste and useless portions of the body, that their contents are of rather a heterogeneous character. But I am surprised that they should be poured into the mass of blood, since being entirely useless, I should suppose they would find their way out of the system by some other channel.

Dr. B.—The fluid in the lymphatic vessels is called *lymph*; it is of a whitish colour, slightly saline in taste, and instead of being composed of very heterogeneous materials, is exceedingly simple in its composition. These and many other facts lately led physiologists to the conclusion, that these vessels could not be the sole agents of absorption, as was generally supposed after they were discovered. The suggestion was often made that the veins had some share in this function, but it was never satisfactorily demonstrated to be so, till *Majendie*, a few years ago, published the results of his interesting experiments.

Emily.—Do, Dr. B., relate some of them, for I am desirous to know on what reasons the lymphatics have been excluded from the absorbent function, and on what ground rests the doctrine of *venous absorption*, as *Majendie's* must be called.

Dr. B.—One or two of the most striking I will relate. *Majendie* having opened the body of a dog, put two ligatures around a portion of the intestinal canal at a short distance from one another, thus insulating it com-

pletely from the rest. He next divided with great care all the chyloferous and lymphatic vessels, the veins and arteries leading to it with the exception of one artery and one vein, and then divided above and below the ligature, so that it remained connected to the body only by one artery and one vein. He then injected into it a decoction of a certain poisonous substance, and in six minutes, it manifested its poisonous effects on the constitution. A pupil of his afterward varied the experiment by leaving the portion of intestine connected to the body only by the chyloferous vessels, instead of an artery and vein. A similar injection being thrown into it, the poisoning did not take place, even at the end of half an hour; but when one of the veins was freed which had been tied but not divided, the poisoning took place immediately. These experiments have since been verified by other physiologists, particularly Messrs. Lawrence and Coates of Philadelphia.

Emily.—Most ingenious and satisfactory experiments surely—conclusive, I should suppose in favor of the doctrine of *venous absorption*. But what then are we to do with the *lymphatics*? We must find some use for them.

Dr. B.—If we deny the power of absorption to the lymphatics, their functions become a matter of great obscurity. It has been suggested—and this is the most probable suggestion that has yet been offered—that the lymph is a highly animalized fluid destined for important purposes; farther than this we know very little.

The functions of which we have now treated, are to be considered as only preparatory processes for the last and most important of all, *nutrition*—the seat of which is in every part of the body. The particles of our food after having undergone those diversified operations which you have heard related, at last become incorporated with the materials, and form constituent parts of the body itself. After a time they lose those properties which fitted them for this purpose, they are taken away.

carried out of the system, and new ones are deposited to supply their place.

Emily.—Amidst such a multitude of operations, how is it possible that no clashing, no interference should take place—that the system should not be destroyed by the action of its own organs !

Dr. B.—See too, amid all this simultaneous renovation and decay, how admirably the forms and beauty of the organs are preserved ! Even the most delicate lineaments of the face, and that intelligent lustre of the eye, which are recognized by all, but defy the power of the master-artist to embody on the canvass or the marble, are retained with striking distinctness through the various stages of life.

Emily.—Can you inform me how long any particle continues a constituent portion of the body ? If they are constantly changing in this manner from birth till death, why certainly at different periods of life, we must be very different persons, and we may justly I think, apprehend the loss of our personal identity.

Dr. B.—Physiologists, I believe, have never yet been able to find an answer to your question. However, you have nothing to fear on the score of your personal identity, for this consists not so much in the matter which composes our bodies, as in the forms which it assumes, and the spirit by which it is actuated.

Emily.—Does not the activity of nutrition vary in the different periods of life ? It seems rational to suppose that it would correspond with the energy of the constitution generally.

Dr. B.—Your conjecture is correct ; nutrition enjoys its greatest activity in infancy and childhood, when the body is not only to be nourished simply, but increased and developed. It is then that the features are most liable to alteration ; that wounds are more readily healed, and fractures of the bones most speedily united.

Emily.—At what precise period in all the varied operations to which the food is subjected, does it undergo

that change which fits it for the purpose of nutrition? converts it from dead matter into organized living particles? Or is this change wrought gradually?

Dr. B.—In all probability, this change is not effected at any particular stage in the route which the aliment pursues, but is accomplished gradually by the various processes to which it is subjected before it reaches its ultimate destiny. When fully and perfectly animalized, it furnishes the materials whence all the parts of the body whatever may be their nature or situation, are to receive their supplies. From the vessels which circulate in the bones, bony matter is deposited; in the liver, it is bile; in the salivary glands, it is saliva, &c.

Emily.—Again I must express my surprise, that amid this great variety of chemical changes, this play of innumerable affinities, there is nothing of interference or confusion. How wonderful! how mysterious!

Dr. B.—To heighten the mystery still more, we find substances not contained in the blood, and which, chemistry, having gone to the utmost limits of analysis, has been contented to call simple bodies. The uniform composition of animals is also an exceedingly strange fact. The flesh and bones of a sheep, as we have before observed, whose diet is exclusively vegetable; of a lion, which subsists on the flesh of animals; and of a hog, which lives upon a mixed diet, exhibit the same chemical composition, and are formed by processes which chemistry has never been able to imitate. As but little or no nitrogen is taken into the system in respiration, it is inexplicable how this substance should enter as much into the composition of herbivorous animals in whose food only a small quantity of nitrogen exists, as in that of carnivorous animals in whose food this principle greatly abounds. Lime likewise, is found in the body in sometimes double the quantity of what is contained in the food.

Emily.—The living system may be considered I think, a real laboratory which enchains our admiration at the

greatness, the extent and perfection of its operations. They are truly the result of a "vital chemistry," as far beyond the reach of man's imitation, as the power that formed this laboratory, is beyond his own.

Dr. B.—We have now finished the account of the organic functions; in our next conversation we shall begin with those of animal life.

CONVERSATION VI.

Nervous system—its progressive developement in the inferior animals—the spinal marrow—nerves—brain—functions of the nervous system—sensation—volition—Mr. Bell's discoveries—theories of the nervous power—Dr. Wilson Philips' experiments—phrenology—comparison of the brain of man and those of the inferior animals—facial angle—instinct—reason.

Dr. B.—The functions of organic life—those which we have examined—are all possessed to a certain degree by vegetables, as well as animals. But the latter class of beings, and particularly, he who stands at the head of it—man, enjoys a higher and nobler state of existence. They are conscious of their own existence and of the presence of things around them ; and they are affected with pleasure or pain, according to the manner in which these objects affect their constitution. For the enjoyment of this function, they are indebted to a complex series of organs called the *Nervous System*. With this alone however, they would have remained imperfect beings, enjoying an existence less enviable than that of the humblest vegetable. Capable of receiving impressions from the external world, the power of acting in consequence of these impressions, of making their condition change as the objects around them change, was obviously necessary to complete the perfection of their organization, and the harmony of relations existing between them and the

general system of nature. To accomplish this latter purpose, we are provided with a system of organs, called *organs of locomotion*.

Emily.—Am I to understand that the latter are entirely subservient to the former organs—acting only when stimulated by them?

Dr. B.—Certainly; no voluntary motion takes place without the action of the nerves,—but this view of the subject must be considered at another time, for at present we must look at the structure of the *nervous system*. In order that you may obtain a clearer notion of this system, we will first examine it in the inferior animals, and thence trace it up into the nervous system of man. In this manner, you will see in a very interesting light, its gradual developement, and the relative importance of its different parts.

Emily.—This system, like the others, I suppose, is simple in the lower animals, increases in complexity as we ascend the scale of being, and finally exists in its utmost perfection in man.

Dr. B.—Yes—but its gradual developement differs from that of the other organs, in one very remarkable point. It is—that in the earliest stages of existence, it is the same in all; take it in the highest state of perfection in which it is observed, and we find that before it could attain that state, it had to pass through all the forms which it possessed in the different classes of inferior animals in their perfect state.

Emily.—If I understand your meaning correctly, the nervous system of man, before it attains the form which we behold, has first presented that of the zoophytes, then that of the worms, then of the shell-fish, then of the fishes, and so on through the whole series.

Dr. B.—Precisely so; and now we will look at the proofs of this doctrine. In the lowest orders of the Zoophytes, the only trace of this system is nothing more than nervous molecules unconnected with one another, disseminated through the substance of their simple, pulpy

structure. In Zoophytes of a little higher organization, the nervous matter appears in the form of minute and delicate threads arranged around the principal organs of nutrition, with other threads proceeding from them in a radiated manner, to go to the different parts of the body. In the next orders we find a series of little knots of nervous matter, called *ganglia*, connected by two nervous threads, still placed around the organs of nutrition. In the *earth worm* belonging to a still higher order, the nervous thread is single, instead of double as before, and the ganglia instead of appearing independent bodies, are merely swellings of this thread, from which proceed single and double pairs of threads alternately. In the first orders which possess senses, we find the anterior ganglia enlarged and sending out filaments to supply the organs of sense. Thus, as the organs of the animals increase, the nervous threads, or *nerves* we may as well call them, increase in number and perfection, the principal mass still being placed around the oesophagus. In the fishes we meet for the first time, the most remarkable modification which the system undergoes. The main nervous cord becomes enclosed in a long case or canal, and take the name of *spinal marrow*, from the long canal which is called the *spine*. But this is not all: at the summit of the spinal marrow, are observed several large ganglia connected together but quite distinct from one another.



This constitutes the *brain*, and here you may see it in this cut. In the brain of the reptiles, we find an addition of two more ganglia. In the birds, these last ganglia are much developed, and in the mammiferous tribes, the brain, instead of being composed of separate ganglia, has the appearance of a single organ, whose parts are no longer divisible into distinct bodies.

Emily.—This cut, then, according to your theory, will also represent the brain and spinal marrow of man, at one period of his existence, will it not?

Dr. B.—Yes ; and to be perfectly convinced of this fact, you have only to compare the figure of the fishes' brain with this of man's, representing the form which it possesses when any traces of organization can be first discerned.

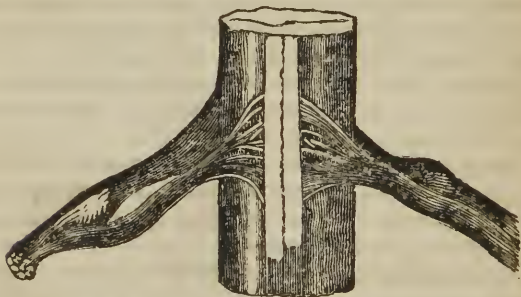


Emily.—Well this is strange indeed ! they seem to be perfectly alike ; at least, I can discern no essential difference. The difference between them however, must be manifested afterwards ; this being the permanent form of the fishes' brain, while in man it is only temporary.

Dr. B.—It is succeeded by the form of the brain, as it appears in reptiles ; then as it exists in birds ; and finally by that which is destined to be its permanent form.

Emily.—But you also said that in the lowest classes, the nerves were formed before the spinal marrow and brain showed any signs of existence,—now is this the case too, in man ?

Dr. B.—Most certainly ; the nerves may be seen quite distinctly, while the spinal marrow is yet in a semi-fluid state. When this is fully organized, the nerves extend themselves to its sides, and join it by two divisions, called the anterior and posterior roots. This figure



will give you a little better idea of it, than you can obtain from mere verbal description. Here you see the

two pairs of nerves proceeding towards the spinal marrow, one on each side, and inserted into it by two roots.

Emily.—But if these two divisions of the nerves, have their termination, not their origin in the spinal marrow, is it not improper to give them the name of *roots*?

Dr. B.—This name was given them when the nerves were supposed to originate from the spinal marrow, and is now retained merely for the sake of convenience.

Emily.—Pray, tell me how many nerves go to the spinal marrow in this manner?

Dr. B.—The whole number of spinal nerves is thirty-one on each side, and are perfectly regular and symmetrical.—Tracing the spinal marrow upwards into the head, we find it terminated by the *oblong marrow*, as a column is surmounted by its capital. Nearly all the rest of the brain is distinguished into two portions, the *cerebellum*, occupying the inferior and posterior parts of the head; and the *cerebrum*, which fills up the remaining space. Inclosed in its bony case, and enveloped by thick membranes, this delicate organ has all the security and protection, which its pre-eminent importance demands. The quantity of blood which it receives is remarkably large, for though it does not weigh more than one-fortieth of the whole body, it is estimated that one-tenth of all the blood sent from the heart, goes to this organ. Its external portions are convoluted in structure, and the whole has a soft, pulpy consistence.

Emily.—Has its chemical composition ever been ascertained? I feel not a little curious to know “what stuff our brains are made of.”

Dr. B.—It has been found that about three-fourths of its weight is water, and in the solid parts are considerable fat, a peculiar animal principle, called *ozmazome*, a quantity of *albumen*, a minute portion of *phosphorus*, and some salts, chiefly *phosphates of lime*, *soda* and *ammonia*.

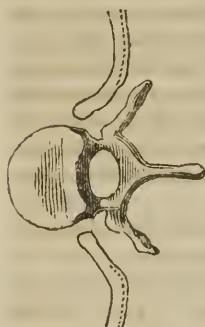
Emily.—Fat, phosphorus, lime and soda! Of all the strange facts which you have related, this seems to be

strangest. Who would suppose these to be the materials which form the noble organ of thought ! Does the brain, like the spinal marrow, receive nerves from other parts ?

Dr. B.—Yes ; we find eleven pairs of nerves connected with the base of the brain, which supply the organs of sense, the muscles of the face, and the muscles concerned in respiration. Coming from these parts, they pass through holes in the bony case of the brain, and run along its base, till they are finally lost in the *oblong marrow*.

Emily.—You observed just now, that the spinal marrow is enclosed in a bony case—the spine or back bone, I believe. I do not clearly perceive how this can be, for I thought that the spine was solid bone.

Dr. B.—I will describe it then, a little more definitely. The *back-bone, spine, spinal column, vertebral column*—for it is designated by all these names—is not



formed by a single bone, but by twenty four small bones piled upon each other. Each bone, as you will see by this figure, is composed of its body and processes ; the first is thick, nearly cylindrical in shape, and its broad flat terminating surfaces connect it with the bones above and below. The processes are those smaller portions of bones, proceeding from different portions of the body in pairs. Two pairs serve to interlock and bind firmly together,

each bone to its neighbour ; while the other pair, after proceeding a short distance from the posterior portion of the body, meet at an acute angle. Now when the bones are applied to each other, the space thus enclosed by these posterior processes, will form a continuous canal from beginning to end.

Emily.—And it is in this canal then, that the spinal marrow is lodged. But why could not the spine have

been formed by one single bone? I cannot possibly conceive what is the use of so many little bones; I should think they would be very liable to be displaced amidst all the motions, falls, and injuries that we are continually experiencing in a greater or less degree.

Dr. B.—If the spinal column were formed of a single bone, the whole neck and body would be completely stiff and unyielding—admitting motion in no direction whatever. In order to admit the various motions of the body, some flexibility is necessary in the spine, and this can be obtained only by forming it with a succession of several small bones, united together sufficiently strong to allow the requisite degree of motion, without at the same time endangering its strength. So firmly are they united, that dislocations are the rarest of all injuries.

Emily.—My proposition was indeed absurd; if I had thought a moment longer I do't believe I should have appeared so stupid. But knowing the names and anatomy of these parts, *Dr. B.*, is of little use without a knowledge of their functions. I suppose that anatomists who have examined the structure and development of this system with so much perseverance, have not neglected to investigate the uses of its several parts.

Dr. B.—Certainly not; a great degree of research and ingenuity has been manifested in their investigations, and they have been followed by some very interesting results. The functions of the nervous system have been reduced to two classes; the *nervous*, and *sensorial*,—or they may be styled two distinct powers of the nervous system. The nervous power is engaged in the performance of vital, or organic actions; the sensorial is the source of sensation, volition, intellect.

The most important functions of the nervous power, are those by which our relations with the external world are maintained. Impressions made upon the organs of sense, are transmitted by the nerves to the *brain*, and

there, by means of the sensorial power, are recognised by the mind, or to use the popular phraseology, become sensations.

Emily.—But how is it known so certainly that the impression is conveyed to the brain by the nerve solely? I should like to be acquainted with the grounds of this doctrine.

Dr. B.—It is demonstrated by the fact abundantly established by experiment and observation, that if the nerve be injured, no sensation is produced in the mind. If the optic nerve, by which impressions made on the organs of vision are communicated to the brain, be injured in any way, no object will be perceived, though its image may fall on the retina just as distinctly as before.

Emily.—I do not perfectly understand how sensations are experienced in the brain; I have always considered their seat to be in the extremities of the nerves, or the organs of sense themselves. Surely, if I grasp a warm body with my hand, I feel the warmth in my fingers, not in my brain; if a wound be made in my arm, I feel the pain in the wound, not in the brain.

Dr. B.—There is a very obvious distinction between *sensations* and *impressions*; the latter are the changes produced in the extremities of the nerve; the former, the changes produced in the brain and communicated to the mind. The mind however, is accustomed to refer the seat of its sensations to the seat of the impressions, which circumstance must be borne in mind, or we shall fall into an error. But we are anticipating this part of our subject, for sensation is an effect of the sensorial power, and we have not yet finished our examination of the nervous power.

Another function of the nervous power is to transmit to the voluntary muscles the stimulus necessary for their action. When I wish to grasp the object before me, the muscles must receive their proper stimulus before they can be put into action. This is conveyed from the

brain, along the nerves, to the parts to be affected, and may be called the *stimulus of volition*.

Emily.—Is this function also demonstrated by experiment, like the last?

Dr. B.—It is well known, that if the nerves which are distributed to a muscle, be divided, that muscle will be found to be entirely beyond our control, however eager our wish, or strong our efforts to move it.

Emily.—It appears then, that when a nerve is divided, it is neither capable of transmitting the impressions made on its extremities, nor of conveying the stimulus of volition to its extremities. Now this double function of the same nerve puzzles me exceedingly, for functions so different, one would imagine, would be executed by different instruments.

Dr. B.—This reasoning always had great plausibility, and its truth has lately been most satisfactorily demonstrated by Mr. Charles Bell. He was first led to correct views of this subject, by thinking on the difference which the nerves of the spine, and the brain, present in regard to their origin, or as we have called it, their termination.

The former, as we have already seen, are connected with the spinal marrow by two roots, and each root with a distinct track or column of nervous matter, three of which columns compose each side of the spinal marrow, and may be easily distinguished through its whole course, and even in the brain itself. If any one of these nerves be divided, both the sensation and the motion of the part to which it leads, are lost. The nerves of the brain, on the contrary, are connected by a single root only, and the division of which, is found to occasion the loss of but one of these powers. Thus, if the optic nerves be divided, the sense of vision disappears, but the motions of the eye are performed as readily as before. To ascertain now, whether this difference of power depends on the kind of connection which the nerves maintain with the brain and the spinal marrow, he determined to divide the roots of the spinal nerves singly,

and watch the effect. The spinal canal was laid open several times in rabbits, and the posterior roots of the nerves of the lower extremities were divided. The animal's motions were not impeded, but the extremity was ascertained to be utterly destitute of sensation. It might be pinched, cut, pricked, or otherwise irritated, without giving the creature the slightest degree of pain. In the next experiments, the anterior roots were divided and the posterior left undisturbed. The limb now lost all power of motion, while its sensibility remained unimpaired.

Emily.—The spinal nerves are in reality, then, double nerves; but do they continue distinct throughout their whole course, even to their extremities?

Dr. B.—They continue distinct, but we are not able to distinguish them on account of their very intimate connection. Each nerve, when minutely examined, will be found to be an aggregate of very delicate filaments, bound up in a common cellular envelope. These filaments are for the purpose, either of sensation, or motion, and they remain distinct from one another in their whole course, from their extremities in the parts which they supply with nervous power, through the spinal marrow, to their termination in the brain.

Emily.—And this too, without any interference with each other! no derangement of each other's functions! Truly there is no end to the wonders displayed in the construction of the human frame.

Dr. B.—Mr. Bell now thought that this view of the functions of the nerves would be confirmed, if after tracing the distinct columns of nervous matter in the spinal marrow, into the brain, he should find nerves of motion connected with the anterior column, and nerves of sensation, with the posterior column. This fact was also satisfactorily established. Again, he saw that one nerve of the brain, the *fifth*, had a close resemblance to the spinal nerves, being connected to the brain by two roots, and he concluded that like them, it was a nerve of

sensation and motion. This opinion was tested by experiment. He divided it in an ass, and the jaw to which it is distributed, instantly fell relaxed, and was deprived of all sensibility. *†*

Emily.—I should think his opinions were established satisfactorily enough now. But what other functions does the nervous power possess? I think you mentioned that these which we have already considered, are not the only ones.

Dr. B.—It is known to possess some influence in the process of secretion, for if the nerve be divided which is distributed to a secreting organ, the secreting process immediately ceases. How this influence is exerted, we do not know. It is also inferred with a great deal of reason, that the nervous power takes no small part in the production of animal heat.

Such are the functions of the nervous power ; and that this power is perfectly different from the sensorial, is capable of unexceptionable proof.

Emily.—I am glad you have mentioned this, for I was just about to ask you for more definite evidence of their distinctness. We cannot distinguish between the impression and the sensation—they seem to be one and the same act, and I confess, I see no evidence why they are not both the result of one general power.

Dr. B.—We know that they are distinct, because one may continue in action while the other is destroyed, or prevented from action. Thus, in some diseases or injuries of the brain, volition, sensation, consciousness may be entirely lost, and yet the process of secretion and the evolution of animal heat be still continued for a considerable time.

Emily.—Hence it seems that impressions made on the nerves, are not transmitted to the brain, and this you considered an important duty of the nervous power.

Dr. B.—We have no right to say that the nerves do not, in such cases, transmit the impressions which they receive, because if we irritate them, we see that the mus-

cles to which they are distributed, are violently convulsed. The fact is, that though the impressions are transmitted to the brain, the sensorial power being destroyed or suspended, does not furnish the stimulus of volition, nor produce sensation. In sleep we see some of the nervous functions suspended; while the sensorial are in full play and activity. We think, feel and will, but not a muscle obeys the stimulus of volition, because the nervous power does not transmit it.

Emily.—I am satisfied now, perfectly. But it appears to me, you have neglected to say any thing of the manner in which impressions and volitions are communicated by the nerves, or in other words perhaps, the nature of the nervous power. This seems to me to be the most interesting part of the subject.

Dr. B.—And it is as obscure, as it is wonderful and curious. Still, little as we actually know about it, there has been no lack of theories to explain its nature, and shed broad daylight upon the dark obscurity. By one of these theories, it was supposed that the nerves had the power of *vibration*, and the word *nerve* itself, which means a tense cord, shows how common this opinion was among the Greeks. This theory, which for a long time had fallen into disrepute, was revived during the last century, with modifications and improvements, by Dr. Hartley. It is unaccountable how such a theory should have ever prevailed, for we can conceive of no part of the animal structure so entirely incapable of the vibratory motions of a tense string, as the delicate, inelastic nerves completely enveloped in the surrounding soft parts. By another theory, the nerves were regarded as capillary tubes which convey a fluid secreted by the brain, and called the *nervous fluid* or *animal spirits*. It is by the oscillations of this fluid, that impressions are communicated to the brain, and volitions to the nerves. It has been a very common doctrine among medical men, and seems now to be an article of popular belief. It is enough to say of it however, that the two essential facts

upon which the whole theory depends have been gratuitously assumed,—the nerves have never been found to be hollow, and the nervous fluid, such as it is here imagined, never existed.

Emily.—Is it possible that with no foundation whatever in truth, this theory could have prevailed so long !

Dr. B.—It seemed reasonable enough that the communication maintained by the nerves, should be effected by means of some material agent, for it was hardly possible to conceive how else it could be done. In accordance with the most common analogies, it was very naturally regarded as an extremely light fluid, or invisible gas. In later times, the nature of that subtle and powerful agent, electricity, has been more fully unfolded to us, and now, the most common theory of the nervous power identifies it with this agent. The modern discoveries in regard to it, very soon showed its strong resemblance to some of the vital actions, and great expectations were raised, that it would be found one day, to constitute an important property, or portion of organized matter.

Emily.—Galvani, I believe, ascertained that if a frog formed part of a galvanic circle, violent and rapid contractions of the muscles took place.

Dr. B.—It is well known too, that the dead body, when properly exposed to its influence, will exhibit some of the most striking phenomena of life. The chest has been made to contract and dilate, as in true respiration ; the fist has been clenched ; the limbs raised ; and the passions strongly expressed in the countenance. The brilliant experiments of Dr. Wilson Philip have particularly called attention to this fluid, and convinced many of its perfect identity with the nervous power. It is well known, that if the nerves which are distributed to the organs of respiration and digestion, are divided, the former function is impeded, and soon ceases, and the latter is effectually destroyed. Now this gentleman divided these nerves in different animals, and connected their

divided extremities with a galvanic battery by which they were supplied with a regular current of the galvanic fluid. The result of these experiments was, that these functions might be maintained in this manner perfectly well for a considerable length of time. For instance, the nerves were divided in two small dogs, soon after they had been permitted to eat as much mutton as they chose. In one of them, galvanism was applied for two hours and a quarter, when he died. On examination, the food was found half digested. The other dog which was not galvanized, died at the end of four hours, when it was found that the food he had eaten, was not in the slightest degree digested, but retained perfectly the appearance it had when it was swallowed.

Emily.—Well, really, if there has been no fallacy in these experiments, how can we resist the conclusion, that the galvanic and nervous powers are but one and the same power? I am sure it seems impossible to me.

Dr. B.—To this opinion it is replied, that these experiments prove merely an analogy between the galvanic and nervous powers,—that they possess some common properties by virtue of which the former may be substituted a short time for the latter,—that their identity is no more proved by their similar effects on the vital actions, than the violent contractions produced in a muscle by pricking it with a pin, or irritating it with chemical and mechanical agents, indicate the nervous power to be identical with any of these agents.

Emily.—This reasoning however, does not satisfy me. The sole object of the nervous power is to assist in the vital actions, and if the galvanic fluid be found to answer the same purpose, at least as far as can be expected considering how it is applied, why, it seems to me almost conclusive proof of their identity.

Dr. B.—Think which way you will on the subject, you will have the satisfaction of knowing that many eminent physiologists are on your side. But to confirm your opinion, behold the following among several marvellous

experiments lately performed by Weinhold. He removed the brain and spinal marrow of a cat, and after all signs of life had disappeared, he filled up the cranium and vertebral canal with an amalgam of mercury, zinc, and silver. The effect was, that the animal soon gave signs of life ; it raised its head, opened its eyes, looked steadily, attempted to walk, and endeavoured to rise after frequently falling down. In the mean time, the circulation was renewed, and the secretion of the gastric juice seemed more abundant than ordinary. The animal heat was also re-established. This gentleman also remarked, that the extremities of a divided nerve gave sparks when brought together.

Emily.—A most marvellous experiment truly, and not without its practical utility too, for perhaps in time, some more perfect composition may be found which will restore even the creature's mousing propensities, and in short, make it once more, sound and healthy as ever.

Dr. B.—We must now turn our attention to the sensorial power. In regard to sensation, we know no more than that a certain series of changes invariably precede its appearance, and that its seat is somewhere in the brain. We can define it only by mentioning these changes which has been already done. In the first place an impression is made from the external world, upon an organ expressly destined to receive, and properly modify it. By means of a nerve in connection with this organ, the impression is communicated to the brain. Lastly, it is received into the brain, and recognized by the mind.

Emily.—Is it necessary, Dr. B., that each of these, stages must be passed through, in order that sensation may take place? What would be the effect of irritating the nerve of vision, for instance?

Dr. B.—The effect would be that neither motion nor sensation would be produced. If the organ, nerve or part of the brain whither the impression is carried, be destroyed or injured, no sensation will be produced.

Emily.—In what part of the brain does this faculty of sensation reside?

Dr. B.—This is a question not so easily answered as might at first sight, be supposed ; for though the brain has been examined with more care, interest, and perseverance than any other organ in the body, yet very little is certainly known of the functions of its various parts. The older physiologists thought there must be some common point in the brain where all the nerves terminated, and whither all the impressions are conveyed. This spot they were accustomed to call the *sensorium commune*, or common sensorium, and it was located in various parts of the brain, according as whim, or hypothesis dictated. As for the source of volition, we know no more than about that of sensation. Many experiments have been performed with the view of throwing light on this subject, but at present their results are too clashing to warrant us in deducing from them, any general truths. As for the intellectual faculties, modern physiologists have been fond of assigning them distinct seats in the brain, and lately this view of the matter has been extensively developed and wrought up into a regular system which is exceedingly plausible and has been received by many—and some very distinguished—physiologists.

Emily.—O, you allude to Phrenology. Do tell me something about this system, for the accounts respecting it are so contradictory that one can hardly tell from them, whether to consider it as the dreams of visionaries, or the results of sound philosophy.

Dr. B.—Such is always the case, when men undertake the discussion of doctrines, with minds already occupied by violent prejudices. But you may be assured, that a science, which within thirty years has been gaining ground so fast, that it now numbers among its advocates some of the most distinguished scientific men of the present day ; that pretends to establish its principles only on numerous and well observed facts, cannot, with the slightest justice, be associated with the fancies of

dreamers, or fanatics, but is worthy the examination of all sound and inquiring minds. According to phrenology, the brain is an aggregate of several organs of a conical form, originating by their apex from a common point in the centre of the brain, and terminating by their base on its circumference. These organs are the seat of the various moral and intellectual faculties, which are distinct from, and in some measure independent of each other. Those to which the intellectual faculties belong, occupy the front part of the head, while the moral and animal passions are exercised by the middle and posterior portions. The strength or capacity of the faculties, is in a direct proportion to the size of these particular organs, and that of the whole brain. The relative size of any particular organ, and the strength of its corresponding faculty may be estimated by examining its termination on the surface of the brain. If it swells above the rest, appearing like a bump or protuberance, the organ is large and well developed, and the faculty will form a prominent feature in his moral, or intellectual character.

Emily.—But Dr. B., when you described the brain, you said nothing of these organs which are the very foundation of the phrenological doctrine.

Dr. B.—They were not mentioned, because in truth they cannot be distinguished. All the other propositions of phrenology may be established by fact, or sound reasoning, but as to the form, size, or even existence of these organs, anatomy gives us no light whatever.

Emily.—May not the strength of any particular faculty depend in some degree on the fineness and perfection of structure, as well as absolute size of the organ. It is not those who have the largest eyes or ears that see or hear best, or those who have the largest muscles that can lift most, and why should he who has the largest organs, or brains, think and feel most strongly?

Dr. B.—Perhaps the perfection of a faculty depends in some degree on organization, but there are strong grounds for believing that it depends chiefly on size.

Emily.—If that were true then, we should always expect that persons possessing large heads, would be likewise men of great intellectual powers, and *vice versa*. But is this the case? Is not the capacity of the mind entirely independent of the size of head?

Dr. B.—Not according to the testimony of the best observers. Those who have given this subject particular attention, are agreed in considering that great mental capacity is accompanied by a large head. Hear what Majendie says—one of the most distinguished physiologists of the age; distinguished not more for the brilliancy of his discoveries, than the philosophical spirit that pervades all his researches. “Generally speaking, the volume of the brain is in direct proportion to the capacity of the mind. It would be incorrect however, to suppose that every man who has a large head, must necessarily be possessed of a superior intellect, because many causes besides the volume of the brain, may increase the size of the head. But it is nevertheless very rare that a man distinguished for his mental faculties, is not found to have a large head.” That the strength, and even the kind of intellectual power is indicated in a great degree by the size and form of the head, is a doctrine of no recent date, but was most distinctly recognized by the ancient artists. The old sculptors never committed the solecism of putting the head of a philosopher on the shoulders of a gladiator; and the character of their Deities, of Jove the Thunderer, of Apollo the patron of the muses and the arts, of Mars the God of brute force, is strikingly indicated by the form of the head, no less than by the features of the face. In the paintings of the modern masters, the same principle has been steadily kept in view, though the doctrines of phrenology never came to their ears. It is every day recognized to a certain extent, by the most ordinary observers, for he who should be liable to mistake the head of an idiot, for that of Bacon or Shakespeare, would be considered almost an idiot himself.

Emily.—As man has greater intellectual faculties than any other animal, then, according to this doctrine, he must have the greatest head, in proportion to his body, of all other animals.

Dr. B.—This does not necessarily follow, because the whole brain is not supposed to be devoted to the exercise of the intellectual faculties. Still it is so generally true, that, at one time it was a commonly received opinion, though many exceptions now brought to light, destroy its force as a universal rule.

Emily.—Do mention some of these exceptions; I am curious to know what animals have a larger brain than the “lord of creation.”

Dr. B.—It has been ascertained that the dolphin, some of the seals, several apes, and some birds, exceed the human species in this particular; and an examination of the proportions of many other inferior animals, shows that the intellectual capacity is not always proportional to the relative size of the brain. Thus, in man, the brain bears to the body, the proportion of 1 to 22, 33, and sometimes 35; in the dog, it is as 1 to 100; in the elephant, as 1 to 500; in the sheep, as 1 to 257; in the horse, as 1 to 700; in the ass, as 1 to 154; in the eagle, as 1 to 260; in the duck as 1 to 257; in the tortoise, as 1 to 2240; in the frog, as 1 to 172; in the shark, as 1 to 2496; in the carp, as 1 to 580.

Emily.—Truly, we may bid good bye to theory now. Here is the ass, the very emblem of stupidity, with four times more brain than his nobler brother, the horse; and the elephant, the most sagacious among brutes, exceeded in point of brain, by the silly sheep. But what are the proportions in those animals which you mentioned as being exceptions to the principle that man possesses the largest brain in proportion to his body?

Dr. B.—In the dolphin, the brain is to the body, as 1 to 25; in the Canary bird, as 1 to 14; in the sparrow, as 1 to 25; in the red breast, a 1 to 32. Thus, you see most strikingly, how such facts are worth volumes of speculation.

Emily.—But may not the human brain after all, be absolutely larger than that of any other animal?

Dr. B.—Such was the belief of the ancient naturalists, and it is certainly less objectionable on the score of exceptions, than the other, for the elephant is the only one I believe that has been found.

Another point of comparison has been instituted, which is more satisfactory than either of these. It depends on the ratio of the brain to the bulk of the nerves which issue from it. This view of the matter flatters our pride more than any other, for man possesses positively the largest brain in proportion to the nerves which come out from it. The apes, whose brain resembles man's so much in form and size, present a striking difference in the size of their nerves. The brain of the horse is 14 ounces lighter than man's, while the nerves in its base are ten times larger.

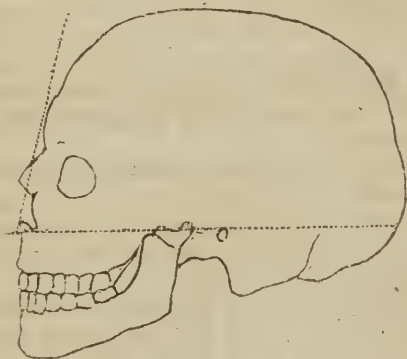
Emily.—Is there no other difference between the brain of man and of the mammiferous animals, than that of size and form? I should imagine there might be some difference in the organization, the one being more delicate and perfect in this respect.

Dr. B.—They all, except the apes, want the posterior portions of the cerebrum. In man, all the parts are more developed, the convolutions are deeper and more numerous, and it approaches nearest the spherical shape. But the most striking characteristic of the human brain, is the prodigious developement of the cerebrum, and especially its anterior portion. The proportion between this part, as it is considered to be most closely connected with the mental powers, and the rest of the brain, is a tolerable index of the mental capacity of the animal.

Emily.—But how can we ascertain this, till after the animal is dead? I do not see how the fact can be of any practical utility, unless we have the means of determining it during life.

Dr. B.—Several rules for this purpose have been laid down by naturalists, but we can mention only that

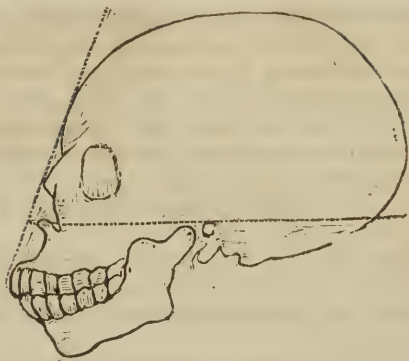
of Camper, called the *facial angle*. He imagines a straight line drawn from the forehead to the upper lip, and another forming an angle with it, from the lip horizontally backwards. As the prominence of the forehead is produced by the cerebrum, the greater the latter is, the greater will this angle be. In a well-formed European head, the facial angle is about 85° , as is represented in this figure ; in some of the Grecian statues



of the gods, it is frequently over 90° , thus indicating the supernatural perfection of the Deity.

Emily.—The poor Negro must suffer sadly by this test, for not only is his forehead low and retreating, but his jaws project considerably—at least the upper one does—a circumstance which will materially lessen the angle.

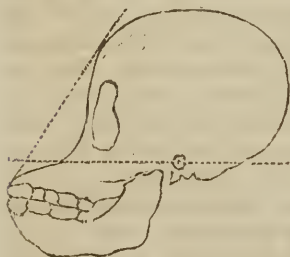
Dr. B.—True it is rather an unfair test, when applied to the Negro, in whom the angle is 7° or 8° less than in the European, as you may see by comparing this next figure, which represents the Negro's skull, with



the first. In all children the angle is much larger than in adults, for at their time of life, the cerebrum is more fully developed.

Emily.—How do the lower animals appear when tried by this test?

Dr. B.—In the larger monkeys, it varies in different species from 70° to 80° , as represented in this figure.



In the sheep and hog, we find it not more than 35° . In the birds, the angle suffers a very considerable diminution not exceeding generally 7° or 8° . In the reptiles, it is still less, and in the fishes it is almost nothing.

It may be remarked generally, that in the European the face is placed nearly perpendicularly under the front of the cranium; in the Negro, and some other varieties of the race, we see it beginning to be placed more in front, projecting forward; and in the lower animals, forming a great part of the head. As we descend the animal scale, this increasing size of the face, including also that of the jaws, indicates very strongly the in-

creasing predominance of the animal over the moral and intellectual nature. If therefore we consider the brain as the exclusive organ of the moral and intellectual faculties, and the rest of the nervous system, as that of the senses merely, then certainly the comparison of the cranium and face, must throw considerable light on the dispositions and capacities of animals.

Emily.—What would be the result of such a comparison in man?

Dr. B.—Man has the largest cranium with the smallest face, and his intellectual, compared with his animal faculties, are greatly superior to those of any other animal.

Reason, or intelligence, whatever we choose to call it, is not peculiar to man, but exists in the brutes in various degrees of perfection.

Emily.—Brutes have *instinct*, it is true, but I thought this was very different indeed from *reason*.

Dr. B.—It is ; but the brutes, as well as man, have a certain degree of each. Instinct impels them to the performance of certain actions necessary to fulfil the purposes of their nature, without premeditation or design. Thus, when the young pup is thrown for the first time into the water, or the new-born babe placed at the maternal breast, it is instinct which impels each to a most complicated series of muscular motions but which are necessary for the preservation of life. But reason, considered as the power of “shaping means to ends,” though possessed in some degree by the brutes, exists in man in its highest state. Its ceaseless action is carrying on the species in its unlimited progress, and indissolubly associating the happiness of the individual, with that of the whole community.

Emily.—And in the brutes too, the deductions of reason, as you are pleased to call it, are confined to the individual—he alone enjoys their benefits. But in man, they constitute a common stock, to which all contribute, and from which, all receive a share.

Dr. B.—What he wants in physical power to constitute him “lord of the creation,” is amply made up by this instrument, by means of which the inferior animals are deprived of their natural independence, and made subservient to his changing wishes. The brute is not taught by it the offices of kindness, nor impressed with a single desire to advance the welfare of his species.—Man alone “feels for man,” relieves his distresses, and rejoices in his prosperity. Give to the reason of the inferior animals as high a character as you please, it still remains the highest and noblest prerogative of man; the faculty that removes him to an immeasurable distance from every other being in the wide creation, and points him to the Divinity for fellowship.

CONVERSATION VII.

The senses—the eye—eye-brows—eye-lids—eye-lashes—tears—sclerotic coat—choroid—cornea—iris—aqueous humor—crystalline lens—retina—modification of the rays by the coats and humors—short-sightedness—motions of the eyes—squinting—vision assisted by the other senses.—Vision of birds—of fishes—of insects.—Hearing—sound—anatomy of the ear—hearing assisted by the other senses—hearing of the inferior animals.—Smelling—use of the sense of smell—smelling of the inferior animals.—Taste—influence of civilization upon taste—taste of the inferior animals—the touch—integuments—human complexion—albinos.—The voice—larynx—larynx of the inferior animals—cries—language—singing—ventriloquism—voice of birds.

Dr. B.—By the organs of the senses, we refer to those by means of which, impressions made on certain portions of the nervous system, are conveyed to the brain, and there excite corresponding sensations. The senses may be said to be the bond of connection in the animal between the external and internal world; and raising the creature above the state of mere vegetable existence, they place him in close relations with the objects around him, and give him an elevated rank in the general system of nature. Each one gives him an entirely distinct set of ideas, which he could have obtained

in no other way. Deprive him of the eye, and where is the beauty of colours? Of the ear, and where is the melody of sounds? Of the nose, and where is the freshness and fragrance of smells? Take away from him all, and he is reduced to a mere vegetable existence.

Emily.—Can we not then easily conceive, how an additional sense, by making us acquainted with the qualities of objects of which we are now altogether ignorant, would give us another set of ideas, and thus enlarge and elevate our capacities?

Dr. B.—Why in truth, there is nothing very chimerical in the idea, for in ascending the scale of animals, we observe the senses gradually increasing in number and perfection, and it is a very reasonable supposition, that five may not be the utmost limit beyond which the possibility of any more is precluded. We cannot, however, wish for any more, for our place in the system of nature is fixed, and our capacities are sufficient for the conditions of our existence. But we must leave these speculations, and proceed to our account of the senses; and first let us consider the sense of sight.

Emily.—Don't be afraid, Dr. B., of being too particular in describing the various parts of the eye, and the uses of each, for I am exceedingly desirous of fully understanding the construction of this curious organ.

Dr. B.—Before we consider the proper organ of vision, we must give a passing notice of its protecting parts. The *eye-brows* are peculiar to man, and when contracted, as in frowning, they serve to protect it from the too strong impression of light, and prevent the sweat, particles of dust, &c., from falling into the eye. The *eye-lids* protect it from the immediate contact of external objects, and this end is still farther promoted by their peculiar sensibility, which excites them to close over the eye instinctively, on the approach of danger. They likewise regulate in a certain degree, the quantity of light which enters the eye; for when the light is weak, or the object at considerable distance, they open widely;

but when it is too vivid, they approach each other, and diminish, as far as necessary, the quantity of light.

Emily.—But what, pray, can be the use of the *eye-lashes*? Or are they merely for ornament's sake; for you know, they sometimes look very beautiful, and moreover, furnish a poet a capital subject for a sonnet.

Dr. B.—I apprehend they were neither designed to add beauty to the human face, nor to inspire a poet's muse, but for purposes of real utility. Their use is similar to that of the eye-brow, for they guard the eye from insects and light substances floating in the air; and so necessary are they in this respect, that persons who have lost their eye-lashes, are always troubled more or less with a defect of vision.—For furnishing the requisite moisture, by which the parts are enabled to glide over each other without experiencing any ill effects from friction, the eye-lids are provided with numerous little glands, from which a watery fluid is secreted. Besides this, there is another fluid, the *tears*, secreted from the lacrymal gland situated at the anterior and outer part of the orbit, (the name of the bony socket that contains the eye.) When any thing irritates the eye, the tears are shed in profusion, for the purpose of washing away the irritating cause.

Emily.—What becomes of the tears when not wanted for this purpose? I suppose nevertheless, that their secretion is continually going on.

Dr. B.—This is readily explained. At the internal angle of the eye, there are several minute orifices leading by a short canal into the nose, by which the tears are conducted off, and thus prevented from coming out and falling over the cheek—a circumstance which would happen if these orifices were closed, as they sometimes are in disease.

Emily.—And the reason why they run over the cheek in crying, is, I suppose, because they are poured forth in too large quantity, to be absorbed instantly by these lacrymal orifices.

Dr. B.—Yes, just so. The organ of vision, and the mechanism by which the rays of light are transmitted through it and variously modified, you must bear in mind, are regulated strictly upon optical principles. The whole globe of the eye is a collection of humors, or thick dense fluids arrayed in a certain order, separated from one another, and enclosed by several membranes of different density and extent, called its coats. These may be arranged in three divisions; the first, serving to modify the rays of light; the second, to receive the impressions; and the third, to transmit them to the brain. And now for those of the first division. The external and enveloping coat of the eye is the *sclerotic*, a strong fibrous membrane, nearly of a spherical shape, which contains and protects the contents of the eye, and preserves its general shape. Lining this, is the *choroid* coat, of a more delicate structure, abundantly provided with blood-vessels, and furnished with a black pigment, called the *pigmentum nigrum*.

Emily.—Is the white of the eye a portion of the sclerotic coat?

Dr. B.—There indeed, you do not see the sclerotic coat, because it is covered by a reflection of mucous membrane, called the *conjunctiva*. If this were stripped off, we should then see the sclerotic coat. The sclerotic coat does not completely encircle the eye; for the anterior portion of the eye is bounded by another coat, called the *cornea*. Its edges are intimately connected with those of the sclerotic; it is the segment of a smaller sphere; and is perfectly colourless, and transparent.

Emily.—Colorless! why I supposed it was this coloured portion in the middle of the eye-ball. I cannot conceive what else it can be, for there is no other part that I can see.

Dr. B.—The part which gives the colour to the eye, is a circular membrane, whose edges are connected with the edges of the cornea, and which stretches across this portion of the eye like a curtain.

Emily.—The cornea then, is in front of this membrane, and of course a space must be left between them. But what do you call it?

Dr. B.—It is called the *iris*, and is the seat of the colour of the eye, which varies you know, by infinite shades, in different individuals.

Emily.—If I understand it right, the iris has a hole in its centre, forming the *pupil*, as it is called ; so that the shape of the iris is that of a flat ring.

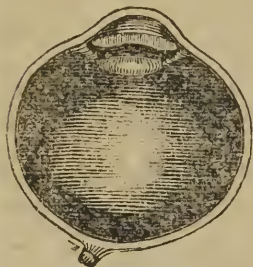
Dr. B.—It is through the pupil that the rays pass ; if the iris was not perforated in this manner, you see they would be entirely intercepted. The iris has also the power of contracting and dilating, and by thus increasing or diminishing the diameter of the pupil, can accommodate the eye to the various changes in the intensity of the light.

Emily.—But what fills up the space that is left between the iris and cornea ? I cannot discern anything, and yet I should hardly think it would be left entirely empty.

Dr. B.—It is filled with a watery, transparent fluid, called the *aqueous humor*. This space is called the *anterior chamber* of the eye—that behind the iris is called the *posterior chamber*. The first thing we meet with in this latter chamber, is a small hard body just behind the iris, nearly of a spherioral shape, and is called the *crystalline humor*, or lens. The remaining portion of this chamber of the eye, is occupied by a dense, tenacious fluid, called the *vitreous humor*, from its resemblance to melted glass.—This finishes the description of the first division of the parts of the eye,—the two others are soon dispatched. Expanded on a portion of the choroid coat, is a very delicate coat, chiefly composed of nerves, and generally considered as an expansion of the *optic nerve*. It is called the *retina*, and constitutes the second division of the parts of the eye. The third embraces only the *optic nerve*, which issues from the back part of the eye, enters the skull through a hole in the

orbit, runs along the base of the brain, and terminates at last in the medulla oblongata.

Emily.—May not your description be illustrated by a plate of the eye? This would now give me a very definite notion of the form and situation of the several parts. O, here, you have one already.



Dr. B.—This may convey a clearer idea of the matter than mere verbal description. It represents a vertical section of the eye in the middle. The external line shows the cut edges of the sclerotic and the white one within it of the choroid coat ; in front you see the edge of the cornea appearing like a sudden bulge of the sclerotic. At a little

distance behind the cornea is the iris ; and between it and the cornea is the aqueous humor. Behind the iris you observe a white body, representing the crystalline lens, and the rest of the chamber is occupied by the vitreous humor. At the posterior portion of the eye, you may see the commencement of the optic nerve.

Emily.—This is quite clear. I think I understand now the structure of the eye sufficiently to comprehend the uses and actions of its different parts.

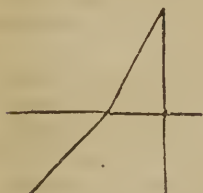
Dr. B.—If you have any wish to examine the eye itself, it is easy enough to procure one of an ox, or sheep, or fish, from the butchers, and by first freezing it, you may cut it open in various directions, and observe all its parts very satisfactorily.

Emily.—I should be delighted to examine one in this way, and will take the first opportunity to procure one.

Dr. B.—Before we can examine the functions of the several parts of the eye, I must call to your recollection a few of the most prominent principles of optics, or the laws which regulate the transmission of light. Rays of

light you know, in passing from one medium to another of a different density, are always refracted, or bent out of their direction. If they pass from a *denser* to a

rarer medium, as represented in this figure, where the horizontal black line represents the latter, the space above, the former medium, and the oblique line, the ray of light, they are refracted from the perpendicular. But in passing from a *rarer* to a *denser* medium, the contrary takes place.



These changes happen however, only when the rays fall upon the surface of the medium obliquely; for when they fall perpendicularly to it, their direction is not changed, whatever may be the difference in the medium. You must bear in mind too, that rays of light proceeding from a luminous object, go on constantly diverging; that

this divergency is increased, by suffering the rays to pass through a concave lens, and counteracted, or the rays made to converge, by interposing a convex lens. The next two figures will illustrate this principle. Now to understand how the rays of light are modified in their passage through the eye, let us consider a single luminous beam falling obliquely on the cornea. In entering the cornea, it is refracted towards the perpendicular on account of the convexity of this part; so that when rays fall on every point of the surface of the cornea, they will be *converged*, and thus the intensity of the light be increased.



Emily.—And in traversing the aqueous humor, this being denser

than the atmosphere, the beam will be still more converged. But what becomes of the rays that fall on the iris? They cannot all pass through the pupil.

Dr. B.—Those which fall on the iris are reflected back through the aqueous humor, and help to produce the peculiar lustre of the eye.

Emily.—They have now to pass through the nearly spherical crystalline lens, which being convex, will, I suppose, still farther increase the convergency of the rays.

Dr. B.—Yes; it will act precisely like a convex lens, bringing the rays sooner to a focus, in their passage through the vitreous humor. On account of the lesser density of the latter humor, they will lose a little of their convergency, till they at last, fall on the *retina*, and there form the image of the object from which they proceed. But this image will represent the object in an inverted position—the cause of which, I presume, you will not need my aid to explain.

Emily.—The rays which enter the pupil from the upper portion of the cornea, will pass on in a downward direction, and fall on the lower part of the retina. Those entering it from below will take an upward direction, crossing the others in their course, and fall on the upper portion of the retina, while the rays which pass through the pupil perpendicularly to it, will strike on the centre of the retina. O, here it is illustrated in this figure.



Dr. B.—If you clearly understand the subject so far, you can, no doubt, readily see what would be the effect of an increase of the convexity or density of the humors, on the image of the object.

Emily.—In that case, I suppose, the rays would be brought

to a focus sooner, or what is the same thing, the image would be formed a little in front of the retina, instead of directly upon it.

Dr. B.—And what means would you take to remedy it, provided such an affection should take place?

Emily.—I am sure *Dr. B.*, I cannot tell any more than the man in the moon. I suppose physicians make use of plasters and drugs, whose very names are enough to terrify one.

Dr. B.—The means I refer to, act on optical principles, and are what you see made use of every day. This change of the humors takes place in *short sighted* people, and is perfectly well remedied by using concave spectacles.

Emily.—These, by increasing the divergency of the rays, will counteract the undue convergency produced by the change in the density of the humors.

Dr. B.—If on the contrary, the humors are not sufficiently dense, and therefore do not converge the rays enough, the focus will be at a point beyond the retina, and the image will be very indistinct. This affection is peculiar to old people.


Emily.—And is corrected by using convex spectacles. I never imagined before, that the defect of vision in old and young people, proceeded from precisely opposite causes—the one from too little, and the other, from too great convergency of the rays. But what are the causes of these defects?

Dr. B.—The former, or that of old people, seems to be the natural consequence of old age, though sometimes it is undoubtedly brought on by other causes—that of being accustomed to look a great deal at very distant objects. The *short sightedness* of young people is chiefly produced by looking at objects placed too near the eye. In children, it frequently is a consequence of their books being held too near. I knew a respectable school where short sightedness was a very common affection among the students, by reason of the desks being

made too high—they almost touched the chins of the smaller boys. In cases of this kind, the defect may be easily remedied if attended to in season, by obliging the child to look frequently at distant objects, and never permitting him to hold his book so near his eyes as he generally wishes.

Emily.—How is it, Dr. B., that the eyes are able to move in such a variety of directions, and move too so exactly together, as always to be directed towards the same objects?

Dr. B.—It is by the aid of several little muscles, that the eyes are made capable of every possible movement and can take cognizance of objects in every direction not absolutely behind. These muscles are six in number; two inserted into the superior, two into the inferior side of the eye-ball. These four by their various combinations of actions, roll the eye in every direction, but at the same time, have a tendency to draw the eye backwards a little. The two others counteract this tendency; one of them as you will observe in this figure, produces this effect by a curious arrangement.



It passes through a loop in the bone in advance of the level of the eye, and of course draws the eye forward, when it contracts. When both eyes are turned in precisely the same direction, the image is formed on corresponding points of the retina, and the mind perceives but one object. When however, the muscles of the eyes contract unequally, we observe that their motions do not correspond; the eyes are turned in different directions, and the person seems to be looking at two objects.

Emily.—This then constitutes the affection called

squinting. Why should not those who squint, behold two objects at once? It is certain that the image cannot be formed in both eyes, on corresponding points of the retina, and you observed that this was necessary in order that the mind should behold but one object.

Dr. B.—Undoubtedly, when people first begin to squint, objects do appear double, but the mistake being constantly corrected, the mind at last becomes conscious of beholding but one object.

Emily.—I think I have heard that the sight of itself alone, gives us no information in respect to the distance of objects, but that this is the result of habit and judgement. This may be very true, but I confess, I do not clearly understand it.

Dr. B.—Have you never seen a young babe stretch out its hands to grasp the moon, or any other distant object? To people also, who have been born blind, but received their sight at an after period of life, objects at a mile's distance, appear to be within their reach. It is by the long habit of comparing together objects at different distances, that we judge of their absolute distance, and not by any original power of the eye. When we look at an object remote from others with which we might compare it, it always appears much nearer to us than it really is. Thus, a light in the dark, will always appear nearer than it actually is, from our being unable to compare it with intervening objects. It is the same in regard to the size of objects in such situations. A man, for instance, when seen from the top of a high steeple, will seem much smaller than when beheld on the same level with ourselves at a much greater distance.

Emily.—I have noticed this fact, but it never occurred to me that it was owing to my not being accustomed to look at objects in a vertical direction.

Dr. B.—So too, the eye alone, unassisted by the other senses, gives us no knowledge of the *forms* of bodies. Unaided by the sense of touch, all objects would present the appearance of a flat, uneven surface.

When we look at a round body, the rays of light proceed only from the side towards us, and yet we never are in doubt of its actual form. We can also judge, with the same degree of accuracy, of the form and size of a book at ten feet distance, as at one, though it is certain that in the former case, the image of the object on the retina is much smaller, and is a plain figure. Objects, in fact, are represented on the retina, in the same manner as in a painting, where, whatever may be their size or figure, they are made with one dimension only ; so that to a person who has just received the sense of sight, external objects appear like the figures in a painting to one—if we can suppose such an one—wholly ignorant of perspective.

Emily.—I recollect having read somewhere, an account of a blind person, whose sight was restored by an operation, in which all these facts in regard to vision, were very pleasantly illustrated. I have forgotten the details of the account, and retain only a general impression about it.

Dr. B.—It was probably the one told with delightful naivete by Cheselden, a distinguished English anatomist of the last century, and is quickly related :—

“When he first saw, he was so far from making any judgment of distances, that he thought all objects whatever touched his eyes, as he expressed it, as what he felt did his skin ; and thought no objects so agreeable as those which were smooth and regular, though he could form no judgment of their shape, or guess what it was in any object, that was pleasing to him. He knew not the shape of anything, nor any one thing from another, however different in shape and magnitude. Upon being told what things were, whose forms he before knew by feeling, he would carefully observe them that he might know them again ; but having too many objects to learn at once, he forgot many of them, and, as he said, at first he learned to know, and then forgot a thousand things in a day. One particular only, though

it may appear trifling, I will relate. Having often forgotten which was the cat, and which the dog, he was ashamed to ask ; but catching the cat, which he knew by feeling, he was observed to look steadfastly at her, and then setting her down, said, so puss, I shall know you another time. He was very much surprised that those things which he liked best, did not appear most agreeable to his eyes—expecting those persons would appear most beautiful whom he loved most, and such things to be most agreeable to his sight, that were so to his taste. We thought he soon knew what pictures represented, when showed to him, but we found afterwards that we were mistaken ; for about two months after he was couched, he discovered that they represented solid bodies, when to that time, he considered them as party-coloured planes, or surfaces diversified with a variety of paint. But even then he was no less surprised, expecting the pictures would feel like the things they represented, and was amazed when he found those parts, which by their light and shadow appeared now round and uneven, felt only flat like the rest, and asked which was the lying sense, feeling or seeing ? Being shown his father's picture in a locket in his mother's watch, and told what it was, he acknowledged a likeness but was vastly surprised ; asking how it could be, that a large face could be expressed in so little room, and saying it would have seemed as impossible to him, as to put a bushel of any thing into a pint. At first he could bear but very little light, and the things he saw he thought extremely large ; but upon seeing things larger, those first seen he conceived less. He never was able to imagine any lines beyond the bounds he saw ; the room he was in, he said, he knew to be but part of the house, yet he could not conceive that the whole house could look any bigger."

Emily.—It must have been very amusing truly, to have seen him so intently examining the cat, and expressing his wonder at his father's picture.

Dr. B.—The same facts are established by many other similar cases which have been observed by physicians and surgeons, but it would be unnecessary to mention them. Among the inferior animals, the eye becomes more simple in its structure, until in some of the very lowest orders, it ceases to exist entirely. In some classes we see, the structure of the eye is modified according to the medium in which the animal lives. Thus, in Birds the anterior portion is remarkably convex, because the rays of light passing through the rarer portions of the atmosphere, suffer greater divergency, and consequently the eye must possess a corresponding power of convergency. In Fishes, on the contrary, the eye is very flat, because the rays before they reach the eye, pass through the water which is a much denser medium than the air. There is a curious form of the eye existing in the Insect tribe, called the *compound* eye. These animals possess two, apparently single, eyes in their head ; but when examined by a microscope, they are found to be composed of an aggregate of a vast number of single eyes ; or rather the external coat which corresponds to the cornea, is made up of these numerous six-sided figures. Every one of these is undoubtedly furnished with a nerve, and is in fact, a perfect eye. In the eye of a common house-fly there have been counted 8000. In Spiders, the eyes are single and are six or eight in number, placed in different parts of their body.

Emily.—They then literally share with man the privilege of “looking before and after.” Their enemies are so numerous however, that they must really need it.

Dr. B.—The next sense to which we shall turn our attention, is that of *hearing*. This sense, briefly defined, is the one which makes us acquainted with the impressions of sound ; and *sound*, you know, is the result of motions communicated to elastic fluids by the vibrations of solid bodies. The organ of hearing is an apparatus most admirably contrived, for collecting sounds, and producing the requisite impression on the nerves, which

communicate them to the brain. No part of the human structure, however, is so complicated, and so difficult to be comprehended by one who has never personally examined it, as the ear. For this reason I shall not perplex your mind with much of its minute anatomy, since the clearest descriptions in the world, even if assisted by plates, would fail to give any thing like an adequate conception of it. The external ear is composed of an elastic cartilaginous substance, which collects the sonorous rays, and may be compared to the large extremity of a trumpet. Thence the sounds are transmitted through the auditory canal which winds along in the substance of the bone. At its termination, there is stretched directly across it a thin tense membrane, called the *membrane of the tympanum*, or drum of the ear. On the other side of this membrane, is a cavity called the *tympanum*, in which is contained a chain of four very small bones, connected with the drum of the ear and the opposite sides of the cavity. An opening into the pharynx, establishes a free communication with the air. Various canals and cavities, closed by tense membranes, lead from the tympanum, containing fluids, in which are expanded the soft and delicate filaments of the auditory nerve. This is enough of the anatomy of the ear, for you to understand how the vibrations are communicated to the nerve.

The membrane of the tympanum on which sounds first strike after passing through the external auditory opening, may be compared to the head of a drum, and the cavity of the tympanum being supplied with air, serves to complete the resemblance to that instrument.

Emily.—The use of the *Eustachian tube*, then, is to supply the cavity of the tympanum with air—but why is this necessary?

Dr. B.—The necessity of such a supply of air will appear very obvious, if you consider that if a drum be exhausted of its air, no sound would be produced. Whether the membrane of the tympanum be under the

control of any muscles by which it is relaxed or made tense, according to the graveness or acuteness of the sounds, as has been conjectured, is a fact on which we have no positive information. Vibrations are produced in the chain of small bones, and in the walls of the tympanum, and thence transmitted to the auditory nerve. The essential part of the organ of hearing, is the cavity containing the soft pulp, in which the auditory nerve is distributed. This is found wherever the sense exists, and where none of the other parts are present, as in some of the lower orders of animals.

Emily.—And is this sense, Dr. B., as much under the influence of habit, as that of sight ?

Dr. B.—Certainly ; hearing makes us acquainted only with the existence of sounds—our knowledge of their distance, direction and nature, is obtained by experience, and the assistance of the other senses. Our knowledge of their direction, seems to depend chiefly on the harmony existing between both ears. If we close one ear, and a noise be made at a little distance from us, it is often impossible to determine whence it comes, though with both ears open, we might not be at any loss to determine. We are considerably assisted also in our judgment of the direction of sounds, by the sight, for in the dark, we often find it very difficult to tell from what point it comes. We judge of the distance of sounds too, by having been long familiar with them, and by frequently comparing them together.

Emily.—I am conscious how liable we are to be deceived respecting the direction and distance of strange sounds—I have often been deceived in this way, myself. Do we not judge of the distance of some sounds also, by their peculiar tone, and when this tone is imitated, are we not easily deceived ?

Dr. B.—Of a truth we are, and this is the secret of the ventriloquist's deception,—but more of that by-and-by.

Emily.—Cannot some people perceive certain sounds

which are entirely inaudible to others, whose hearing is nevertheless acute enough in regard to common sounds?

Dr. B.—Yes, there are a few sounds of this kind, but they are all extremely low.—Different sounds have the power of affecting the ear—that is, the physical organs, agreeably or disagreeably. The harsh grating of metals or other hard bodies on one another, is offensive to every ear; the babbling of a brook, and the song of birds, are on the contrary, agreeable to all. The sensation is also greatly modified by the manner in which sounds are combined. Sounds made from musical instruments at random by the unskilled and ignorant, are always unpleasing; but when arranged in a certain order, and directed by skill and taste, they are a source of the most delightful sensations.

Emily.—What is the cause of the great difference that exists among people, in regard to the manner in which they are affected by musical sounds? Is it any difference in the structure of the ear? We hear of people having a *good ear*, and a *bad ear* for music.

Dr. B.—This language is literally incorrect,—people have confounded that mere physical delight which some sounds will produce in every one, with that internal satisfaction which arises from the perception of harmony between musical sounds. The former is altogether physical, like the pleasure derived from the sense of smell and taste; but the latter originates from a distinct faculty of the mind, which, like those that give an excellence to some in poetry, painting and other arts, is a gift of nature not bestowed on all.

In examining the organ in the inferior animals, we see its different parts vanishing one after another, until we come to some of the shell-fishes, where we find neither external ear, tympanum, nor bones, but merely some membranous sacs, in which are expanded the minute filaments of the auditory nerve. Fishes, and some reptiles have no external passage to the ear; the only communication is by the Eustachian tube.

Emily.—But, Dr. B., do fishes possess the organ of hearing?

Dr. B.—Fishes probably surpass all other animals in acuteness of hearing; owing in some measure perhaps, to the nature of the medium through which the vibrations are conveyed. Water, you know, must be a much better medium for conveying sounds, than air. Some few fishes, in fact, possess the rudiments of an external ear.

Emily.—Some of the inferior animals have one advantage over us, in the structure of their hearing organs. They can change the position of their external ear, so as to correspond to the direction whence the sound proceeds. This is particularly manifest in the horse, rabbit, &c., and these animals, if I mistake not, have the sense of hearing extremely acute.

Dr. B.—Of the remaining senses, we have but little to say, as the organs are extremely simple, and their functions can be observed by all. *Smelling* is the sense which makes us acquainted with the presence of certain particles given off and diffused to various distances, from *odorous bodies*. “The smelling apparatus may be compared to a sieve placed in a spot, over which the current of air that is introduced into the chest in respiration, passes, and which is destined to detain all the foreign bodies which may happen to be mixed with the air, particularly odours. This apparatus, in the first place consists of the *pituitary membrane*, which lines the back part of the nostrils and other cavities which communicate with them.” On this membrane, are distributed the minute and numberless ramifications of the *olfactory nerve*, or the nerve of smell. By this, the impressions made on the membrane, are communicated to the brain. In order to protect this delicate expansion of nerves thus freely exposed to the air and to the painful stimulus of acrid and pungent odours, the membrane is kept constantly moist by a secretion of mucous fluid from the glands, with which it is provided. The sense of smell

is one of quite inferior importance in the animal economy of man. It furnishes the mind with few ideas, and those are subservient exclusively to his physical nature.

Emily.—I have known several persons who never possessed the sense of smell, and I did not see that they suffered any material inconvenience from the want of it. Though they were insensible to some very pleasant sensations, they were at the same time, spared the pain of many disagreeable ones. In short, I do not see but that it might very easily be dispensed with.

Dr. B.—You are now giving it a lower rank than it actually deserves. In the savage state of man, it no doubt furnishes him with very useful hints in regard to his food, but now its natural acuteness is weakened and perverted by the refinements of artificial life. But as it is, we often reject an article of food, if unpleasant to the smell, without waiting for the opinion of the taste to confirm our decision. Who, after smelling tobacco, or henbane for the first time in his life, would ever think of tasting it?

Emily.—Sometimes this sense seems to possess a morbid degree of acuteness in respect to some odours, which is highly inconvenient and even dangerous. I have heard of persons who were always thrown into convulsions at the smell of cheese, certain fruits, flowers, &c. The sense of smell is much more acute in some of the inferior animals than in man, is it not?

Dr. B.—In brute animals generally, the sense exists in greater perfection, than in man; and it is by this sense that they distinguish with such wonderful accuracy the food provided for them by nature, and know how to choose between the evil and the good. Though constantly feeding among noxious vegetables, they are seldom deceived, but select from the poison around them, pleasant and wholesome nutriment. In some of the higher orders, there is an astonishing acuteness of the smell in regard to the effluvia that come from living

animals. By thus making them acquainted with the presence of their enemies or their prey, when the eye and ear are incapable of acting, it possesses an importance in them, far beyond what it has in man. A traveller in Africa relates, that they were always apprized of lions being in their vicinity during the night, by the moans and trembling of their horses.

Emily.—I have read too, that the American bison will snuff the effluvia of man, for the distance of many miles. And think how accurately a dog will track his master merely by his scent.

Dr. B.—Spurzheim mentions one which followed his master through several countries in Europe.

Emily.—How does the sense exist in the lower orders of animals—the Fishes, for instance.

Dr. B.—Fishes possess it in a remarkable degree of acuteness. This is well manifested in the nicety they exhibit in regard to different baits employed in taking them. Thus, a worm that has lost its flavor by long maceration in water, will be refused by a fish ; but the same worm, after having its odour revived by fresh incisions made into it, will be taken greedily. In the orders still lower, the sense is quite obscure, and we know but little about it.—We must now consider the sense of Taste, and so simple is its nature, that I presume you can easily define it yourself.

Emily.—It is the sense which makes us acquainted with the impressions produced on the tongue by *sapid bodies*. There—am I correct ?

Dr. B.—The tongue is the principle organ indeed, but the sense is possessed in some degree by the lips, sides of the cheek, and palate. These parts are all abundantly provided with vessels and nerves which are expanded beneath the lining membrane, and form little eminences called *nervous papillæ*. These are the seat of the impressions, which are transmitted from them to the brain. In order that the sense may be perfectly

exercised, the mouth must be constantly supplied with saliva, and the other secreted fluids. In fevers and other diseases in which the secretions are changed, this sense is always imperfect and vitiated. Placed thus at the entrance of the alimentary canal, all our food is first subjected to its scrutiny, before it is conveyed to the digestive organs. No sense has been made to vary so much by the refinements of social life, as that of Taste. The taste of wild animals and of savage man, is the same in all individuals of the same species—they all probably, like or dislike the same food. But among civilized men, no two individuals can be found alike in all their tastes; and so general and well understood is this diversity, that one would as soon think of disputing another's conscience, as his taste.

This sense may be considerably improved in acuteness, by long training. Those whose business requires them to judge of the qualities of objects by their taste, acquire in time a nicety of this sense, which is inconceivable to others. The acuteness of taste in different persons, varies according to the sapid bodies themselves; some, very readily tasting what others do not.

Emily.—This fact, I recollect is very pleasantly illustrated in Don Quixote, by the story of two wiseacres who were tasting wine. One thought the wine tasted—a little—of leather; the other was very confident, that he tasted—iron. The wine was at last drank up, when looking into the vessel, lo! there was found an iron key with a leathern thong attached to it.

Dr. B.—The taste grows imperfect in the Birds, becomes still more so in the Reptiles, and is entirely wanting in the Fishes, and other animals.

Emily.—How is this fact known in regard to Fishes?

Dr. B.—It is inferred from the structure of their mouth, and from the indiscriminate manner in which they swallow any thing that has the appearance of prey. A mackerel will swallow a piece of red flannel, with as

much avidity as any other bait, and in sharks there have often been found ballast-stones, marling-spikes, hatchets, and similar articles. Besides, owing to the sameness of their food, and consequently, the little necessity of discrimination, this sense was obviously not required.—But we must conclude our account of the senses, with the last and most general of all, that of Touch.

Emily.—This sense makes us acquainted with a great variety of the physical properties of bodies, form, dimension, consistence, smoothness, motion, &c. Its seat seems to be as general as its powers—being the whole surface of the body.

Dr. B.—The sense of touch must not be confounded with that of mere feeling which merely apprizes us of the *contact* of foreign bodies, without giving us very definite ideas of their qualities. However, the former seems to be only a more perfect kind of the latter, and the seat of both is near the surface of the body within its *integuments*. These integuments, included under the general term of *skin*, are described by anatomists as composed of several distinct strata or layers, different in appearance and name. The most internal, that which constitutes the chief bulk of the skin, is called the *Dermis*, or true skin. It is strong and compact in its texture and chiefly composed of countless myriads of minute arteries, veins, nerves, &c. which traverse it in every direction. From the nerves which are distributed over every point of its surface, it receives that acute and delicate sensibility which renders it preeminently fitted to be the organ of touch and feeling. Its colour is very nearly the same in all the varieties of the race, and depends entirely on the state of the minute blood-vessels. “According as they are full or empty, it may vary (as we see it in the white races) from a more or less florid red, constituting what artists call flesh-colour, to the waxy paleness of fainting, or exhaustion from hemorrhage.”

Emily.—Do you really mean that the colour of the skin is the same in all mankind? If such is the case, why then I have always been in an error respecting the seat of colour. Does not the poet speak of a fellow-being having a “skin not coloured like my own”?

Dr. B.—Yes—but neither poets, nor any other persons are bound, in the familiar use of words, to adhere to their strict anatomical meaning. The seat of colour is not in the true skin, but in another part which we shall describe presently.

The external layer of the integuments, or *epidermis*, as it is called—which is very well seen when raised by a blister—is formed by minute scales lapping over each other, as in the skin of a fish. From their extreme minuteness, this structure is visible only under a powerful microscope. It is said to be furnished with neither blood-vessels, absorbents, nor nerves, and its only use seems to be to afford protection to the more delicate parts beneath. Its colour is nearly alike in the fair as well as dark coloured races, but it is generally a little deepened by exposure to the rays of the sun.

Between these two layers, we find one still more delicate, called the *rete mucosum*. Its nature is very imperfectly known; it is not decided whether it be an extremely fine net-work of capillary vessels, filled with variously colored fluids, or merely an unorganised pulp. This layer has never yet been discovered in the white races, though there can be little doubt that it does exist, and that it is in consequence of its extreme delicacy alone, that it has eluded observation.

Emily.—Why should it be so much more easily discovered in the Negro, than in white people?

Dr. B.—Because, in the former it is of a black color, and is perhaps thicker, though it is so extremely thin and delicate that no small nicety of dissection is requisite, in order to find it. When removed and placed in water, it diffuses itself in the fluid, and gives a turbid

cloud to it. The most important fact however, in regard to the *rete mucosum* is, that it is the seat of colour—of those diversified tints which characterise the various races of men.

Emily.—But is its colour permanent—never changed by exposure to the heat of the sun?

Dr. B.—Never—but generation after generation, in this climate or in that, it is the same; as unalterable as any other feature of the human structure.

Emily.—Well, I always supposed—indeed I have often read it books of high authority—that the colour of the body depended solely on the action of the sun's rays, it shades being deepened according to the intensity of the heat and light. Negroes, you know, live in the torrid zone, brunettes in temperate, or moderately warm latitudes, and light florid complexions, as those of northern Europeans, in colder climates.

Dr. B.—If you are disposed to resort to facts, and are willing to examine them impartially, you will find that you have gone to the wrong source to find proofs of your opinion, for they afford the most satisfactory demonstration of its incorrectness. Some blacks do indeed live in the torrid zone, but the whole continent of New-Holland, the southern extremity of which extends to the 40° of south latitude, abounds with inhabitants whose complexions are as black as the Negroes'. In the polar regions, men instead of being uncommonly white, as they should according to your theory, are very tawny. Throughout the whole American continent, excepting the arctic regions, the copper tint prevails with very little variation.

Emily.—But it is a fact that Europeans and others who have been educated in a temperate climate, will acquire a deep shade of brown after a few years' residence in hot countries, and will regain their original tint generally, when they return home. Now it seems very reasonable to believe that the colour of the black races

has been acquired by long exposure to the action of intense heat and light.

Dr. B.—The change which you allude to, is precisely like that called *tanning*. Its effects are quite superficial and temporary, and disappear when the part that experiences the change is renewed. The Moors have lived in Africa ever since the seventh century, and still their children are born as fair as those of Europeans. The Negroes have lived in the New World more than two hundred years, and their color is as black as ever. The farther we go into the examination of facts on this point, the stronger will be the confirmation of the fact, that the human complexion is independent of climate, or in truth of any other known physical cause.

Emily.—I acknowledge myself convinced by your proofs, and will cheerfully give up my theory. But if the *rete mucosum* as you call it, has never been found in white people, what proof is there that it does really exist?

Dr. B.—The white races are not destitute of colour by any means; some indeed, are quite brown, as the Spaniards, Greeks, &c. Now if the *rete mucosum* is the seat of colour in blacks, there is good reason to believe that it is also, in the whites. Besides, there are sometimes born among the blacks and other dark-coloured people, individuals who are entirely white, but it is a colour very different from that of the white races. It is a dirty white or cream colour, and the skin has sometimes a remarkable roughness.

Emily.—You refer now to the Albinos, do you not? I had the pleasure of seeing one a few years ago, and not only was the complexion unnaturally white, but the hair was white, or rather silvery, and the eye-brows and eye-lashes were of the same tint. The iris was of a light rose colour, and the pupil red. What is the cause of this strange phenomenon? I have understood that it is not unfrequent among the negroes. Humboldt has observed it among the South American Indians, and Dubois says it occurs in India.

Dr. B.—It is owing to a deficiency of the rete mucosum which contains the colouring substance, and it sometimes occurs in the inferior animals. White specimens have been found of the rabbit, ferret, mouse, weasel, fox, bear, beaver, rhinoceros, camel, elephant, buffalo; the crow, black-bird, canary-bird, partridge, and a great many more.

Emily.—And it is this peculiar appearance of the skin when the rete mucosum is known to be absent, which induces you to think that it may be present in the white races, and be the seat of their various tints? Well, the argument seems to be sound, and for want of a better, I will adopt your opinion for the present.

I should like to know however, what the use of the black rete mucosum can be to the Negroes; or, if any purpose be answered by it, which is not by the white one of other people.

Dr. B.—Sir Everard Home has tried some experiments, the result of which proves that the black colour enables them to resist, in a remarkable degree, the radiant heat of the sun's rays.

Emily.—Pray, what were these experiments? Black I always thought, absorbed heat, and of course, made the body hotter over which it is placed.

Dr. B.—This is true of unorganized matter, but not so it seems, when we speak of this colour in reference to animal bodies. However, I will relate the experiments, and you may judge for yourself. This gentleman, among other experiments, exposed the backs of his two hands to the sun's rays, with a thermometer upon each, one hand being covered by a piece of black cloth under which the back of the thermometer was placed, and the other being freely exposed without any covering. The result was, that though the thermometer under the cloth stood four or five degrees higher, than the other, yet in every one of these trials, the exposed hand was scorched, while the other did not suffer in the slightest degree.

At another time, when the thermometer in the sun

was at 90° , the concentrated rays were applied to a piece of black kerseymere, made tight round the arm twelve minutes, without giving pain, or leaving any impression on the skin.

Emily.—Did not the cloth in this case serve to protect the skin, and would not the same result have followed, if white cloth had been used?

Dr. B.—No ; for the experiment was repeated with white kerseymere, the heat being at 86° ; in fifteen minutes, a blister was formed and coagulable lymph thrown out. At another time, a white handkerchief was used, loose upon the hand, and an inflammatory blush was produced over the surface, of several inches extent.

Emily.—So, then, the colour of the negro serves, in a measure, to protect him from the scorching effects of a vertical sun.

Dr. B.—But we must drop this digression, and go back to the sense of touch. All the skin is endowed with feeling though in different degrees ; the palms of the hands and soles of the feet, you know are exceedingly sensible. The sense seems to reside more immediately in the *cutaneous papillæ*, a set of minute bodies to be seen on the surface of the dermis, and composed of blood-vessels and the extremities of nerves. The touch resides chiefly in the hands, whose structure eminently fits them for this function. Their integuments are thin and flexible, and abundantly supplied with nerves and vessels. The motions of the hands are likewise free and extensive, and by means of the fingers, the object is touched at several points at once.

The sense of touch is far more perfect in man, than in the brutes, and has often been considered by philosophers as contributing in a very high degree to his elevation in the scale of being.

Emily.—Buffon, I believe, even thought that much of the difference in men's minds arose from the different degrees of perfection in which the sense is possess-

ed, and considered it very important, that infants should be allowed the free use of their hands.

Dr. B.—These views are extremely unphilosophical and have no foundation in truth.

Emily.—Do brutes possess this sense in any degree? It seems difficult to conceive of the sense of touch, without either thumbs or fingers to exercise it.

Dr. B.—Nevertheless, it may and actually does reside to a certain degree of perfection in other parts. In the racoon, it exists in the toes of the fore feet; in the opossum, it is evidently exercised by the tail; in the horse, ass, and ruminant tribe, it is quite acute in the lips and tongue; in the elephant, it is in the end of the trunk; and in the pig, the snout is the organ of touch. In the bats, the skin which covers the ears, wings, &c., possesses such a perfect sense of touch, that when flying along in the air, they can tell by the difference in its reaction, when they are approaching any object.

Emily.—And they will fly equally well after they have been entirely blinded, according to some experiments that have been tried on them.

Dr. B.—We must now turn our attention to the *Voice*, another of the animal functions. Though not included among the senses, it is of no less importance in enlarging the relations of the animal with the external world, and is possessed by man in common with many of the inferior animals.

Emily.—Do you mean seriously, that voice is possessed by brutes? If so, I have never been so fortunate as to hear them speak, though I am conscious some of their speeches are recorded in Gay's Fables, and sundry spelling-books.

Dr. B.—Your pleasantry all happens to be made at your own expense; for you have mistaken *voice* for *language*—two very different things. The latter refers to articulate sounds, expressive of definite ideas, and is indeed the prerogative of man; the former includes all sounds made when the air passes through the wind-pipe,

either to or from the lungs, and is possessed by all animals, and those only, that are provided with lungs. In this figure, you see the trachea surmounted by a sort of capacious box, formed by thick cartilaginous walls. This part is called the *larynx*, or organ of voice. It is this which forms the prominence in the front of the neck, called Adam's apple.



Emily.—What a whimsical name for an organ of the body. Pray, what did it originate from?

Dr. B.—There is a story recorded by some of the old anatomists, that when Adam swallowed the apple, it stuck in his throat, and produced this prominence which has ever since been faithfully transmitted to his posterity.

Emily.—A fact well remembered, and ought to be borne in mind when the curiosity of our common mother is made the subject of witicism.

Dr. B.—The larynx is provided with a number of muscles, the use of which is to move it as a whole, or its different parts on one another. It opens at the top into the pharynx by a longitudinal slit, or chink, called the *chink of the glottis*, about eight lines in length, and two or three in width.

Emily.—It is this chink which is covered by the *epiglottis*, and is closed in the act of swallowing, I believe.

Dr. B.—The same; at its inferior portion, we find the two broad ligaments stretching across, one from each side, and leaving between, a longitudinal slit opposite to, and very similar to that of the glottis. These ligaments can be relaxed or made tense, and are set into rapid vibrations when the air rushes through them.

Such is the structure of the organ of voice ; yet, simple as it is, the mechanism of this function, is far from being established. It is agreed on all hands, that the voice is formed at the moment when the air traverses the larynx, but physiologists are not agreed as to the part which these ligaments act. Some have supposed that while vibrating, they produce sounds like the strings of a violin, and have given them the name of Vocal Chords. Others have compared them to the reed of a clarionet, while some have supposed that the sound is produced, not by the vibrations of these ligaments, but merely by the rushing of the air through the narrow opening of the glottis ; by these, the larynx has been compared to a flute, or whistle.

Emily.—The truth is, I suppose, that the subject is a very obscure one, and every one who speculates upon it, likes his own theory better than his predecessors'. But let us see what they amount to.

Dr. B.—We cannot enter into a discussion of their merits, for it would lead us too far into the science of sounds. It may be remarked, merely, that it is certain, that these ligaments—the vocal chords—do vibrate when the voice is produced, and that they either produce, or essentially affect the sound. But the organ of voice cannot be called a flute, a violin, nor a clarionet ;—it is a larynx, an instrument which art has as yet but imperfectly imitated.

Forming now, in your mind, a distinct idea of the human larynx, you will readily understand the points of resemblance and difference between it and those of the inferior animals. Among the mammiferous animals, there is not one whose larynx is not provided with the same apparatus as man's ; while in many we find parts which he has not. So that with more complicated organs, most of these animals produce only inarticulate and disagreeable sounds.

Emily.—If then their larynx is formed like man's, how are we to account for their inability to produce ar-

ticulate sounds. I had always supposed that they were destitute of some parts of the vocal organs.

Dr. B.—All we can say about the matter is, that the functions of voice is not needed by them, and therefore they are not provided with it,—they can gratify all their natural wants, and fulfil the purposes of their being perfectly well without it.

In some of the apes, the vocal organs have a curious structure. There is connected with the larynx a bony, or a membranous sac, either single and placed in the middle of the neck, or as in some species double, one on each side extending the whole length of the neck. From these sacs there is always a free communication with the cavity of the larynx.

Emily.—May not the inability of uttering sounds in these creatures, be attributed to this arrangement? Or is it, after all, solely the result of moral causes?

Dr. B.—When this peculiarity of structure was first brought to light, philosophers thought that they had found out for certain, the true reason why apes do not speak, but further researches proved that there exists many species of apes in which this peculiarity is not found; and yet they are just as destitute of the art of speech as the others.

Emily.—How does this arrangement effect the production of sounds in these animals?

Dr. B.—The voice of those with the bony box, is exceedingly intense and disagreeable. The Alouatte and Ouarine, two species in South America, have long attracted the attention of travellers by the intensity and harshness of their cries, and hence have received the name of *Howlers*. “Their cry, or rather horrible rattling screams which they make, may well inspire terror, and seems as if the forests contained the united howlings of all its savage inhabitants together.”

In the larynx of the dog, sheep, cat, ox, &c. we find the same number of parts, and the same arrangement, as in man,—the principal difference being in the width and

thickness of the ligaments, and in the shape of the epiglottis.

The larynx of birds differs from those already described chiefly in this, that they have no epiglottis and that the vocal chords and proper cavity of the larynx is in the chest—in the lower part of the wind-pipe, just where it divides into the bronchiæ to go to the lungs, and the chink of the glottis of course being still at the summit of the wind-pipe. The former parts have been called by anatomists, the inferior larynx; the latter part, the superior larynx, as if there were really two larynxes in birds.

Emily.—But in which of them, pray, is the voice formed?

Dr. B.—It is the opinion of Cuvier that it is formed in the inferior larynx alone. He cut off the wind-pipe of a black-bird near its middle, and then shook him, in the same way as he would have done to make him cry in the natural state. His cries were very perceptible, though much more feeble than before. The same experiment was performed on a mag-pie,—it continued to cry, and its cries were not less intense than in its natural state.

Emily.—I have heard before of hens and turkeys uttering hoarse cries, after their heads were cut off, but never imagined it was a fact observed by physiologists, and explained by anatomical reasons.

Dr. B.—This structure produces a remarkable difference between the voice of birds and other animals. In the latter, the voice being formed at the top of the wind-pipe, it cannot be modified by its length or size; while in birds, the voice being formed at the bottom of the wind-pipe, it is necessarily modified by the length and size of this part, and of the opening at the top, for it must traverse all this space before it can come to the mouth.

Emily.—And is it found to be the case that those with long wind-pipes have the lowest or gravest voices, and those with short wind-pipes, the highest or acutest

voices? For the longer a tube is, you know, in which a sound is made, the lower will be its pitch.

Dr. B.—The fact is confirmed satisfactorily by observation, that in different birds, those have the highest voices which have the shortest wind-pipes, and *vice versa*.

In the vocal organs of birds, we find some curious forms of structure, which so far as we are acquainted with the subject, do not seem to have any particular purpose. Some of the Gallinaceæ order, among which we may mention the domestic cock, the pheasant, some

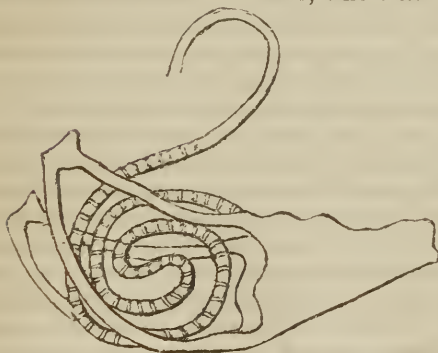
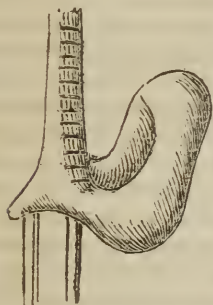
river birds, some of the anseres, as the swan, and some wild ducks, have large inflated pouches connected with the inferior larynx, and communicating freely with it.—

Here is the larynx of a wild duck, differing very little, however from that of our domestic duck. In some river birds, the wind-pipe is convoluted or coiled round upon itself. Here is a specimen of this structure in the wind-pipe of a crane, where its convolutions are

contained within the sternum or breast-bone.

In some other species however, it is not enclosed in the sternum. What is a little remarkable, this structure is frequently possessed by one sex,

and not the other, of the same species. The voice in nearly all those birds whose wind-pipe is convoluted in



this way, is uncommonly harsh and disagreeable, and not very intense.

Emily.—You say these birds with convoluted tracheæ have not intense voices, but the crane and swan are large birds, and we should think they would have intense voices.

Dr. B.—It is found by observation that the intensity of the voice in birds, depends on the strength of the muscles connected with the vocal organs, and it is not true that the strength of these muscles is always proportioned to the size of the bird.

It has been found by Mr. Hunter, that in singing-birds, the loudest songsters have the strongest muscles connected with their vocal organs. The English lark whose voice is so intense that it may be heard after he has risen in the sky out of sight, has the most powerful muscles of all the singing-birds.

Emily.—As Shelly beautifully speaks of it—

Like a star of heaven
In the broad day-light,
Thou art unseen, but yet I hear thy shrill delight.

Dr. B.—The organs of voice in reptiles are much less complicated in their construction than in all other animals, and hence their voice consists of a mere croaking, hissing sound. In the adder, viper, and the serpents in general, we find only a glottis, and of course, the voice is imperfect in proportion to the imperfection of the organ. Serpents are not known to utter any other sounds, than mere hisses, and those only when enraged. The tortoises seem to be unable to utter any sound whatever.

Emily.—The frogs have no reason to complain that nature has not endowed them with vocal powers of no contemptible strength and volume.

Dr. B.—Having now spoken of those “various instruments with which, animals, each playing his part, perform the great concert of nature,” we shall speak more particularly, to continue the figure, of the music itself. Man like other animals, is capable of uttering

cries, by which he expresses his most simple instinctive wants and passions.

Emily.—For this reason, the cry is termed the *natural voice*, I suppose, being a gift of nature, and common to the new born babe, as well as to the adult in years.

Dr. B.—In contradistinction to this, is what is called the *acquired voice*, including speech and singing. “Cries generally include the most intense sounds that the voice is capable of forming, and are characterised by a peculiar tone which easily distinguishes them from all other sounds. They establish important relations between man and his fellow creatures. A cry of joy imparts pleasure, a cry of grief excites pity, and the cry excited by fear carries terror to a distance.” In whatever situation man is found, he is capable of uttering cries. The new born infant, the decrepit old man, the deaf person and the idiot, are all capable of uttering cries; and we must therefore consider this function as essentially depending on organization. The social wants and passions not being inseparably connected with organization, have no peculiar cries.

Man endowed with reason and the sense of hearing, in a state of society, soon perceives that his fellow creatures utter other sounds than mere cries, and by imitation he is enabled to make similar sounds. This is called *acquired voice*, and inasmuch as it is the result of hearing, and of an intellectual effort, the deaf child, as he never hears, cannot imitate the sounds of others; nor can the idiot, for he is incapable of establishing any relations between the sounds he hears, and those he is able to produce.

Emily.—Have the *deaf and dumb* the organ of hearing only defective? I presumed their vocal organs were also defective.

Dr. B.—No—their vocal organs are perfectly sound, but remain forever in complete inactivity, because they are never stimulated by the wish of uttering sounds.

Emily.—I had no idea that speech is so exclusively a thing of imitation. A person then who should be secluded from all society from infancy, would be destitute of the power of speech.

Dr. B.—Not precisely so, neither, for the power of hearing still remaining, he could not help becoming acquainted with some kind of sounds. Hence he would be capable of uttering articulate sounds, though they would be obscure and unintelligible to every body else. Every individual speaks the language that he has learnt from others ; in the situation you refer to, he could learn no known language, but would form one of his own, though it would amount to nothing more than a confused jumble of strange sounds. However, to remove all doubt from your mind, let me relate a curious story illustrative of this doctrine, which I have on undoubted authority :—

Several years ago, there lived in the county of Washington, State of Maine, a family, of which the children, though having the sense of hearing perfectly, and being apparently as active and intelligent as other children, could not talk. They lived in a thinly inhabited part of the country, and at two or three miles' distance from any other family. The father at length grew very anxious, fearing there was a physical defect in their vocal organs, and requested some intelligent gentlemen in a neighboring town, to examine the children, and say whether any thing could be done for their relief. These gentlemen accordingly went and found the children active, sprightly, and able to understand whatever was said to them, as far as any children could be expected to, who had lived in such seclusion from the rest of the world. The oldest one was thirteen years old and could pronounce distinctly several common words and phrases, as *yes sir—no sir—milk—bread—door*, &c. and so could the next oldest ; but they were incapable of pronouncing any sentence of six words. What was remarkable, they had a language of their own which

consisted of signs and a jumble of articulate sounds not belonging to any known language, and by these means, they could easily carry on a conversation with each other. The true solution of this strange affair soon suggested itself to the gentlemen present. They knew that both the parents—very honest and industrious people—were remarkable for their taciturnity,—they never spoke except when it was absolutely necessary to speak, and then they practised the most rigid economy in the use of words. It was directly explained to their parents, that the children could not talk for a very good reason—they never had an opportunity to learn—they never had heard any body talk. The father was therefore persuaded to remove with his family to his native town in Massachusetts where his children would necessarily meet with other children, from whom they might learn to talk. This he did, and in a short time his children talked as well as others.

Emily.—A curious story indeed, and with few parallels, I suspect. It reminds me of one, however, of a similar nature, which I have read in some history of the Egyptians. The king of the Egyptians ordered a couple of young children to be confined alone and supplied with proper nourishment, but to hear the sound of no human voice, for the purpose of seeing what language they would use, and hence determining which was the most ancient nation. After a time, it was found that they frequently exclaimed, *bekkos*, a word which it was ascertained meant *bread* in the Phrygian language; hence it was concluded that the Phrygians were the most ancient people. The author remarked, that they probably learnt this sound from the goats which supplied them with milk.

Dr. B.—It is hardly necessary I should remind you, that articulation is performed not in the larynx, but in mouth by the aid of the tongue, teeth and lips. It is peculiar to man, though imitated to a certain extent by parrots, and some ingenious mechanical inventions, a specimen of which has been lately exhibited in this country by Mr. Maelzel.

Emily.—You allude to the little doll-like figures that uttered *papa*—but I did not suppose there was any thing very wonderful in this.

Dr. B.—Mechanicians have considered the imitation of the human voice by mechanical contrivances, as one of the most masterly efforts of art. M. Kemperlin the original inventor of the Automaton Chess Player, succeeded in constructing a figure which would utter a continued sentence, but the manner in which he obtained this result is now not known.

The elementary sounds which the vocal organs produce are very few in number, not more than twenty, and some reduce them to ten. These sounds by their various combinations, make up those compound sounds of which every language is formed.

Emily.—In the same manner, I suppose, that seven notes in music are made capable of expressing every variety of harmony that has been, or can be made.

Dr. B.—In our own language, the elementary sounds amount to twenty-four, though some of them are but slight modifications of others. The *vowels*, *a, e, i, o, u*, are formed by the chink of the glottis alone; the *guttural*, *k, ch, q, g, h*, are formed in the throat, which is assisted in some degree by the chink of the glottis; the *nasal*, as *m, n*, are formed near the nasal fossae; the *lingual*, as *l, r*, chiefly by the tongue; the *labial*, as *b, p, f, v, w*, by the lips; and *dental*, as *c, t, z, d*, by the teeth.

The voice of speech, like the natural voice, consists of sounds not easily appreciated; that is, not easily reduced to a definite scale, as are the sounds of the voice of song.

Emily.—But do not the various inflections of the voice set down by writers on elocution, show that something of this kind may be done?

Dr. B.—It is true, they do, but in a very imperfect way.—Singing, like speech, is the effect of a state of society, and supposes the existence of hearing and intel-

ligence. Of all instruments which the musical art employs, the human larynx is indisputably the most perfect. It cannot have escaped your observation, that in men, the larynx is much more prominent, than in women; indeed, it is rarely conspicuous in females, except in such as have been wasted by disease. You may also have observed that the voice of the adult male is an octave lower, than the voice of females and boys.

Emily.—I have always observed this difference, but never thought of asking the cause of it, purely, I believe, because it is so common a fact. I suppose that the organs are differently formed, are they not?

Dr. B.—They differ principally in their size—being smaller in females than in men; of course, the voice will be a little higher, reasoning on mechanical principles. The extent or compass of the human voice in well-formed sounds, seldom exceeds ten notes; but the compass of the male voice may be extended four or five notes by the use of what is called the *false* *setto*, which resembles the treble voice.

Emily.—Voices not only differ in pitch and intensity, but every one has its own peculiar tone which distinguishes it from all others, so that we remember a person's voice as long as we do his countenance. Besides, the voice, generally speaking, is distinguished by other characters,—these are *strong* voices; *soft*, *harsh*, *flexible*, *melodious* voices, &c. Are all these the result of organization?

Dr. B.—Undoubtedly, the great diversity in pitch, tone and character of the voice, results mainly from diversity in the structure of the vocal organs, though some change in this respect, may be effected by education.

Emily.—The different degrees of excellence with which people sing, are also, I suppose, to be attributed to the organization of the vocal organs.

Dr. B.—To a certain extent, they are, but not entirely. The power of singing, that is, of producing the notes of the musical scale correctly in various combina-

tions, depends on the accuracy of the ear—the intellectual ear, I mean, or, as the phrenologists would say, *the organ of tune*. The perception of musical sounds, evidently belongs to a distinct intellectual faculty, for the ear may be able to distinguish very accurately, common sounds, and yet the individual be insensible to the perception of musical sounds.

Emily.—And yet we hear it observed every day, that this, or that person has no voice for singing.

Dr. B.—Such language is incorrect, for if a person can talk, he can utter the notes of music, and this is all that is required of the *voice* in singing. A person's voice may be harsh, weak, or unpleasant in any way, but if the taste be good, the voice is always capable of intoning correctly within certain limits. In good singers, indeed, the vocal organs exist in a state of great perfection, so that the mere sound of their voice imparts a pleasurable sensation to the physical ear. But the most wonderful perfection of the vocal organs, is probably found in ventriloquists.

Emily.—I am glad that you are going to speak, before we quit this subject, of *ventriloquism*. Do explain wherein consists the secret of this curious art. It would appear at first sight, that these persons had some peculiarity of construction in their vocal organs, but I believe this is not the case. The name *ventriloquism*, would indicate that the voice is formed in the abdomen.

Dr. B.—This name was given to it when a great mistake prevailed in regard to its nature, and is altogether improper now. The voice of the ventriloquist in fact, is formed in the larynx, as in ordinary speech. You recollect when we were speaking of the sense of hearing, it was observed, that we easily learnt to distinguish the distance and direction of sounds by a certain peculiarity of tone not easily described. The sound of a person's voice undergoes different modifications, according as it is near or at a distance, comes from above or below, from the room or

the open air, &c. Now the ventriloquist having the organ of voice in great perfection, and having been accustomed for a long time, to pay particular attention to the difference between these various modifications, becomes able at last, to imitate them so perfectly as to deceive the most wary. Thus, he knows very well how a voice sounds which comes from the opposite side of the room, and his endeavor is to imitate that sound. If he succeeds, it will seem to come from that quarter, though it is indifferent where he may be placed. If other delusions are made use of, the deception is still more complete. "In one respect," says Majendie, "this art is to the ear, what painting is to the eye."

Emily.—What wonderful results will not education produce, with some of our physical organs ! Who, on hearing the voice of ventriloquism for the first time, would attribute it to this cause !

Dr. B.—No one, we may safely say, for almost every possible theory was started, before the true one was suggested. But in all this perhaps there is nothing more strange, than the power by which hunters imitate the voices of animals, and thus decoy them to their snares.

We might here conclude the subject of the voice, but as many interesting observations on the voice of birds have been recorded, I cannot help making you acquainted with a few of them.

Emily.—Do by all means—for who that has heard the sweet voices of these little songsters, can find any information relative to them, tedious or uninteresting ?

Dr. B.—To *chirp*, is the first sound which a young bird utters, as a cry for food, and is different in all nestlings ; so that the hearer may distinguish of what species the bird is, though the nest hangs out of sight. This cry is very weak and querulous ; it is dropped entirely as the bird grows stronger, nor is it afterwards mingled with its song.

The *call* of a bird is that sound which the bird is able to make when about a month old ; it is in most instances,

a repetition of one and the same note, is retained during life, and is generally common to both male and female. This stage in the notes of birds, is called *recording*, and is the first attempt of the nestling to sing,—it may be aptly compared to the first attempts of the child to talk. At first, we are not able to perceive the least rudiment of the future song, but as the bird grows older and stronger, we see what he is aiming at. When the nestling is once sure of his strain, he commonly raises his voice, and sings out boldly; but he hurries over those parts of which he is not perfect master, lowering his voice as if he could not yet satisfy himself, and did not wish to be heard. The young bird commonly continues to record for ten or eleven months, when he is able to execute every part of his song, which afterwards continues fixed, and is scarcely ever altered. When the bird is thus perfect in his lesson, he is said to sing his song *round*.

Emily.—Every species, I believe, has its own peculiar song—does this difference of song depend on a specific difference in the structure of the vocal organs?

Dr. B.—It would seem very rational to suppose, that the physical organs being different, the sounds they produce, would be so of course. Yet it has been said that the song of birds is no more innate, than language in man, but depends on the master under which they are bred—so far at least as their organs will enable them to imitate the sounds they hear. In proof of this opinion, many experiments have been related, in which birds have been taken from the nest while quite young, and removed to those of a different species. The results were, that the birds thus removed, had the song of their foster parents, and not of their own species.

Emily.—These experiments then are perfectly satisfactory, I should think, in proving the truth of the opinion, that their songs are learnt, and not innate.

Dr. B.—So it would seem, but most unluckily four or five years ago, (these experiments were performed in the last century) an intermeddling naturalist took it into

his head to institute a series of similar experiments, and lo ! their results were just the reverse. How to reconcile them, is more than we know, so that for the present we must be content to have no opinion on the subject.

Emily.—Verily, I think we are like the metaphysical ass between two bundles of hay, starving to death for lack of a sufficient motive to prefer one to the other.

Dr. B.—How birds originally came by the notes which are now peculiar to each species, we do not know ; nor do we know why every nation has its peculiar language and music. The power of singing belongs but to few species of birds and is mostly confined to the males. In their wild state they do not generally sing more than two weeks in the year.

Emily.—Now however agreeable all this singing may be to us who hear it, I cannot, for my life, comprehend what important purpose in the economy of birds themselves, is answered by it.

Dr. B.—It would puzzle a wiser head than mine to enlighten you on this point. It has been supposed that the motive of the male bird in singing, is to amuse and solace his partner, during the tedious process of incubation. But surely this motive cannot induce birds kept in cages to sing as they do, nine or ten months in the year.

Emily.—How accurate to, is the ear of singing birds ! They readily learn any song from one another, and learn many of our common tunes from the flute or flagelet. I saw two or three years ago, in Boston, several robins which an old man had taught to sing yankee doodle perfectly. The mocking bird will sing almost any short strain after hearing it once or twice, and I have known a parrot which is not a singing bird, sing part of a catch with accuracy. Instances of Canary and other birds learning our music, are very common.

Dr. B.—But the accuracy of a birds' ear appears still more remarkable in this fact—that they always sing in the same key ; and it is owing to this that we never

hear a bird unable to complete his strain, as we often are, by taking a pitch above or below the compass of the voice.

Emily.—Have there been any attempts made to reduce their songs to our musical notation? It would be quite pleasant to have the songs of some birds written out, and play them on the piano.

Dr. B.—Such attempts have been frequently made, but in most instances an insurmountable difficulty is found in the minuteness of their intervals. The smallest interval in common use in music, you know is the semitone, and although much smaller intervals are used in harmony, they are not easily appreciated in simple melody—probably on account of our being so accustomed to the grosser intervals. In some instances however, we find no difficulty in writing the notes of birds on our staff. The song of the cuckoo, is a well known and striking instance of this, in which the interval of minor third occurs. But our time is too far gone, to say any more on this subject.

CONVERSATION VIII.

Locomotive organs—bones—composition of bone—ossification—nutrition and reparation of bones—joints—skeleton—skeleton of the lower animals—adaptation of the human skeleton to the erect position—human foot and hand.—The muscles—attachment of the muscles to the bones—action of the muscles on the principle of the lever.—Standing—mechanical contrivances in the leg of birds—walking—leaping—running—influence of education on the muscles—gymnastic exercises.

Dr. B.—Having finished the functions of the nervous system, we come next to those of the locomotive organs ; those by which we are enabled to act upon foreign objects, and transport our bodies from place to place according to the suggestions of the will. The organs of motion may be divided into classes ; the *active*, and the *passive*—the former composing the muscles ; the latter, the bones. And first let us speak of the bones.

Many of the inferior animals have in the interior of their bodies and limbs, a certain series of bones connected together by a definite method of arrangement, which so far as it exists, is generally the same in all. This series of bones is called the *skeleton*. It constitutes the basis and support of the soft parts, and gives to the body its general forms and dimensions. The substance of which a bone is composed, is of two kinds. That composing the external portion of the bone, is of a hard com-

compact texture ; while the centre is occupied by a substance of more soft and spongy nature. The proportions of these two parts vary in different bones, and in different portions of the same bone. Thus, the compact substance composes chiefly the shaft or body of the bone ; while the head and the other extremity of the bone is formed almost wholly of the spongy substance surrounded by a thin covering of the compact. In the centre of the long bones, a hollow space is left which is filled by a fatty substance, called the *marrow*.

Emily.—I cannot comprehend what purpose is answered by this spongy structure, which composes so great a portion of the bone. To me it seems to increase unnecessarily the size and weight of the bones, without adding in the least to their strength.

Dr. B.—You are entirely mistaken,—for the very effect of this kind of structure is to increase the strength of the bone. If the compact parts of the bone were all united together into a solid piece without any space in the centre, the bones being diminished in size, would more easily yield to external force ; for it is demonstrated by mathematics, that the same quantity of matter in the form of a hollow cylinder is capable of resisting a greater external force, than in the form of a solid cylinder, the length being the same in both. Hence, it is generally found that in those parts of the body where strength is required without much additional weight, the bones have considerable spongy substance in their centre.

Emily.—And the marrow—what is the use of this ? A store of nourishment laid up for the use of the bone ?

Dr. B.—It cannot be for the nourishment of the bone, and yet it is difficult to say what its actual use is. It has been supposed to be diffused through the substance of the bone, and thus to render them less brittle. It has also been conjectured that its use in the animal economy is the same as that of other animal oils, and that the centre of the bones being a very convenient reservoir, it was placed here for this reason simply.

Emily.—What is the chemical composition of the bones? I should imagine that strong materials were required.

Dr. B.—The bones are formed of two kinds of substance, one animal, the other earthy. The latter serve the purpose of giving the necessary firmness and solidity to the bone; but this alone being exceedingly brittle, a certain portion of animal matter is obviously required, to give it flexibility and power of resistance.

Emily.—Pray how do you know so exactly what are the particular uses of these two different substances. I should like to see some little more satisfactory evidence of it, than the mere assertion of the fact.

Dr. B.—You have noticed no doubt, how brittle, bones are, that have been burnt in the fire,—now if these be analysed, they will be found to have lost all their animal matter. On the other hand, here is a bone which has been kept some time, in a jar of diluted muriatic acid, and you see that though quite a stout bone, I can easily bend it up double without breaking it.

Emily.—Well, that is singular indeed! But you must have the kindness to explain it.

Dr. B.—The acid has united chemically with the earthy portions of the bones and removed them, leaving behind only the animal matter, which being very flexible yields to the least force. Do you see now, that bones formed of either of these substances alone would want either firmness or flexibility; but that being composed of both, they possess a proper share of both, these qualities?

Emily.—Yes—I see perfectly well now, how both strength and flexibility are obtained by the union of these different kinds of substance.

Dr. B.—You have seen children perhaps, effected with the disease called rickets, when the limbs sink under the weight of the body. Here, owing to some defect of nutrition, the bones are not supplied with their proper portion of earthy matter. The contrary takes

place in old persons—the bones are furnished with too little animal matter. Hence, in falling, old people are more liable than young persons to break their bones.

Emily.—What are the earths found in the composition of bones?

Dr. B.—If we except a small portion of two or three other salts, the earthy substance of the bones, is almost entirely *phosphate of lime*—constituting about one half of the whole bone. This earthy salt, you know, is insoluble in water, and will bear a very high temperature without decomposition. Hence, as might be supposed, bones are the most durable of all parts of an organized body, and capable of resisting, for an astonishing length of time, the influence of external agents. Bones are now found in the earth by geologists, of animals that must have perished long before the last revolutions that have changed the surface of our globe. The animal substance of bones is probably cartilage,—at least it very nearly resembles that substance—with a small quantity of jelly and oil contained in the spongy substance.

Emily.—The bones being one half mere earth, cannot, I should suppose be very sensible, and yet we often hear people complain of pain in their bones.

Dr. B.—This is probably an illusion, for bones in a healthy state may be sawed, cut, scraped, or broken without causing the least pain, and therefore it has been considered by some physiologists, that they possess no nerves.

Emily.—Is it known that they possess blood-vessels, and absorbents? Do they bleed when cut or broken?

Dr. B.—The latter fact is not necessary to prove the existence of blood-vessels. Though we can see no traces of blood-vessels in the bones, yet many observations and experiments, confirm us in the belief beyond all manner of doubt, that the bones are organized bodies, and of course require arteries, veins, absorbents and nerves.

Emily.—I should like to hear some of these experi-

ments and observations, for I really feel more interest in this account of the bones than I had anticipated.

Dr. B.—Attend then, with all patience, to a few remarks on the formation, nutrition, and restoration of bone. We may examine an animal in the first periods of existence—the chick in the egg, for instance—and observe the general shape of the body and the rudiments of limbs, but find no traces whatever of bone. In their place, we observe a soft, semi-fluid substance contained within a delicate membrane. This, after a time, assumes the consistency of cartilage, transparent, and colourless, but possessing the form of the future bone. Next, the vessels which before carried only white fluids, enlarge and give admittance to the red particles, and the first mark of ossification may be considered this appearance of a little artery, filled with red blood, pursuing its way into the substance of the cartilage. Other arteries appear in it from different directions, overtake the first, and finally form a net-work of minute vessels. Here bony matter is deposited from the mouths of these vessels, and at length we have a little centre or nucleus of ossification, spreading in the form of fine rays, in all directions. In this manner, arteries appear in other parts of the cartilage, and form centres of ossification, which spread and meet each other, and thus the whole bone is completed. In the long bones, there are several centres of ossification; the body and each extremity receive a set of vessels which enter it by a common trunk; and these parts are each perfectly formed before they are united together—indeed, in some of the bones, they remain several years after birth, before they are united by any thing more than cartilage.

Such is the way in which bones are always formed; the plan is first laid in cartilage—an isolated mass, without holes or cavities—and is afterwards moulded into its proper forms, during the process of ossification. The cartilage, you see, is not hardened, nor converted in any way into bone, as the older physiologists believed, for

while the bony matter is depositing, a process of no less importance is also going forward. The cartilage is absorbed too, not merely where the bony matter is deposited, but so as to leave the necessary cells, cavities and holes, which are to exist in the future bone.

In the union of broken bones, we find a strong confirmation of what has been said on the formation of bone. When a bone is fractured, there is soon poured out from the vessels of its divided extremities, a soft, fluid matter—chiefly the coagulating portions of the blood;—this gradually becomes cartilage, vessels containing red blood appear in it, bony matter is deposited, and finally a ring of bone completely surrounds the broken extremities, and cements them together more firmly than before the fracture. It is not necessary that the ends of the bones should be placed in direct apposition, that union may be produced. Cases frequently occur, where, by bad management on the part of the surgeon, the broken ends slip by each other, and are not restored to their proper position. Here they are connected by a bridge of bone, which is made between the overlapping extremities, uniting them firmly to each other.

Emily.—What a curious and admirable system of means truly, does this account of the formation of bone unfold !

Dr. B.—The wonder does not cease here, for the process of the preservation and nutrition of bone is equally curious with that of its formation.

Emily.—What is the necessity of nutrition? When once formed, will not a bone continue for life?

Dr. B.—Certainly not; you forget that bones must grow with the growth, and strengthen with the strength of the body; that they are always composed in part of living matter, and consequently subject to continual change. As in the other parts, so in the bones, each particle after a time becomes unfit for the purposes for which it was originally deposited, is taken away, and new ones supply their places. The fact of this constant

change and renovation is tested by experiment, and the rapidity with which it takes place, is almost incredible. It has been found by examination, that when animals are fed on madder, it penetrates into the bones and tinges them with its colour. In twenty-four hours, the bones are tinged, and in two or three days, the colour is much deepened ; but if it be discontinued for a few days, the red colour will be found to have entirely disappeared. A striking proof of the rapidity with which deposition and absorption is carried on in these parts.

Emily.—Are the bones enclosed in any sheath, or investing membrane? I should presume they would not lie in direct contact with the other parts.

Dr. B.—They are all invested by a thin fibrous membrane, called the periosteum, which by means of its numerous vessels, gives nourishment to the external portions of the bone. An injury therefore, which deprives any part of the bone of its periosteum, causes the death of those parts ; they become detached for want of nourishment, and their place is supplied by new ones formed from the parts immediately beneath them. The internal cavity of the bone is also provided with its proper membranes which in the same way transmit the vessels that nourish the adjacent parts of the bone. If now you fully understand this account of the formation and nutrition of bone, we will proceed to the next division of our subject.

Emily.—Thus far, I believe, I have a clear idea of the processes you have described, and they are surely, not the least wonderful in the system of the animal economy.

Dr. B.—The bones in the human body amount in number to about two hundred and sixty, and exhibit a great variety of size and figure. They are nevertheless divided into three classes ; the *long*, *short*, and *flat* bones. The short bones are found in those parts whose motions are confined, but complicated, as in the hand and foot. They present considerable extent of surface, with but

little weight, for they are spongy in their texture. The flat bones are used to form the walls of cavities, as the skull. The long bones are found in the limbs, and are entirely employed in locomotion.

Emily.—How are bones connected together at the joints, so as to give them the wonderful strength, as well as facility of motion which they enjoy? If I am not deceived, I suspect there is much that is exceedingly curious in the construction of these parts.

Dr. B.—Yes—the structure and use of the joints do present us some very interesting facts. They are distinguished into those that are *moveable*, and those that are *immovable*. A specimen of the latter, we have in the teeth and the head; but it is the former kind that we wish more particularly to examine. Physiologists have pointed out two kinds of the moveable joint; the *ball and socket* joint, and the *hinge*. Of the former we have a specimen in the hip-joint. The head of the bone presents a large round surface, which is received into a deep cup-like socket in the hip-bone, in which it plays with an easy motion in all directions. In the elbow is an instance of the hinge-joint. The fore-arm bends forward on the arm, but in its motion backward, it is stopped when on a line with the arm, by a process of bone which juts out from its extremity and comes in contact with the other bone.

In the construction of the joints, every thing shows the regard that has been paid to the security and easy motion of the parts thus connected together. The ends of the bones are, in the first place, surrounded by a thin coating of firm and elastic cartilage.

Emily.—I do not see how this can produce an easier motion, than if the ends of the bones were naked and perfectly smooth. Besides, cartilage being a substance less hard than bone, would certainly wear out sooner.

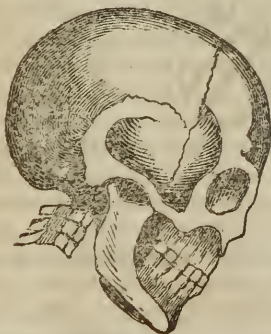
Dr. B.—But though sooner exhausted, it is at the same time, more speedily repaired, than bone. Provision for preventing the effects of friction, can be more easily provided also, in case of cartilages than bones.

Emily.—Pray, what may these provisions be? I never was aware of the existence of any other provision, than the mere vitality of the parts.

Dr. B.—In all the moveable joints, we find a membrane furnished with little glands, which pour out a soft and viscid fluid; this lubricates the joint, and by thus keeping it constantly oiled, as it were, obviates the injurious effects of friction. This fluid is called the synovia, and is poured out in increased quantities, when the joint is in use; it seems as if motion was the proper stimulus of its secretion. When, however, motion is continued too long, the synovial glands are stimulated beyond measure, a soreness is felt, and an irritation is thus created in the joint, which may proceed to inflammation, and serious consequences ensue. This effect may also be produced by very different causes, that is, not a sufficient quantity of motion to occasion the flow of the synovial fluid.

Emily.—You have not yet mentioned by what means they are connected at the joints so strongly and securely.

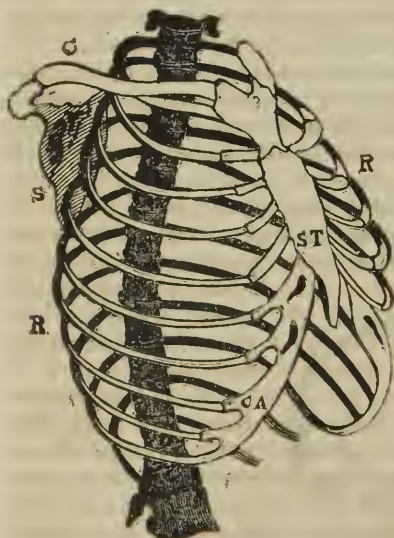
Dr. B.—This is done by means of very thick strong ligaments which go from the extremities of the bones in various directions, keeping them in their respective situations, and limiting their movements on each other. In the hip joint a very broad ligament—the thickest and strongest in the whole body—completely surrounds the whole joint, forming a sort of bag in which the bone moves with perfect freedom.



Thus connected together, the bones form what we have already termed the bony skeleton. At the summit we observed the globular bony box, called the skull, composed of several flat bones united by

means of the little processes which project from the edges of each bone in a saw-like manner, and interlock with one another—a sort of union styled in carpentry *dove-tailing*. Just below the skull and in front of the spinal column, we observe the bony cage formed by the ribs and breast bone, containing the organs of the chest. Terminating the spine, we find the *pelvis* a hollow, basin like cavity formed by three large and broad bones. To the chest are attached the upper extremities, and to the pelvis, are attached the lower extremities. On the upper and posterior side of the chest, and bound down by the powerful muscles of the back, is a broad flat bone terminating above in a short process with an articulating surface, and is called the scapula or shoulder blade.

S P



S P

- C. collar bone.
- S. shoulder blade.
- R. R. ribs.
- S. T. breast bone.
- G. A. cartilages.
- S. P. Spine



To this is attached the round head of the shoulder bone. To prevent this from falling forward, the collar bone runs from the sternum to the point of the shoulder on both sides, and thus separates the shoulders and keeps them securely in their position. This completes the whole skeleton.

Emily.—I think you remarked when entering on the subject of the bones, that many of the inferior animals possess a skeleton, though it is different in some respects from that of man. Wherein does this difference consist?

Dr. B.—Chiefly in the want of certain parts, for the only ones which they all have in common, are the skull and spinal column. The whales and porpoises have no lower extremities; and in the snakes and fishes, we find neither upper nor lower extremities; neither thorax, nor pelvis. The higher order of quadrupeds, such as the apes and monkeys, possess a skeleton which in the general arrangement of its parts, very nearly resembles man's; but there are still some very important characters in the latter, which clearly distinguish it from all others.

In the first place, we can see throughout its whole conformation a constant adherence to that plan of construction and disposition of the parts, which is best adapted to the erect stature. The position of the head on the spine affords a strong proof, of how the principle of the erect position predominates through the whole structure. The human skull is connected with the spine nearly in the centre of its base, and is slightly inclined to preponderate forward, yet it is so nearly balanced, that but little muscular exertion is necessary to keep it in equilibrium. In all other animals on the contrary, the skull is connected with the spine, at its back part; it projects very little behind, almost the whole base being in front of the spine. Now, this arrangement requires for the support and motions of the head, a large mass of muscles on the back of the neck, and particularly a powerful ligament, the rudiments of which only are found in man.

Emily.—I am conscious of this peculiarity in the position of the head in some brute animals, such as the horse, ox, sheep, &c., but I never observed any difference in this respect between the monkeys and man.

Dr. B.—Nevertheless, in the most perfect of the ape kind—those that most nearly resemble man in the point of structure—the space occupied by the base of the skull in front of the spine, is twice that behind.

Emily.—After all, I do not clearly understand how this arrangement indicates the erect position of man.

Dr. B.—Why, if he should attempt to go about on all fours, the very few and small muscles of the neck would be utterly incapable of supporting the head, and it would inevitably fall forward.

Emily.—This seems satisfactory enough, but have not some philosophers imagined that man in a state of nature, as they call it, did actually go on all fours, but had learnt to assume the erect position on account of its greater convenience?

Dr. B.—True, there have been men who would degrade our noble species to a level with the brutes, in its origin, but few will be found, I suspect, at the present day, to advocate their notions. The construction of the human thorax, shows also, how thoroughly this reference to the erect position has been kept constantly in view. In all other animals, its greatest diameter is from before backwards, but in man alone, it is flattened anteriorly; its greatest diameter being from side to side. The tendency of this arrangement you will readily perceive.

Emily.—If it extended to the front, rather than to the sides, its tendency to fall forward would evidently be greater, but the necessary room being obtained by extending it at the sides, the preponderance forward is greatly diminished. Am I right?

Dr. B.—Yes; it likewise gives greater breadth to the shoulders, and consequently more extensive motions to the arms. The human breast-bone also is remarkably

short, whereby a large space is left between the chest and pelvis unprovided with any bony support. The weight of the internal organs being in a downward and not in a forward direction, the muscular walls of the abdomen are sufficiently strong to receive their pressure.

Emily.—Which would not be the case, I presume, were the natural position of man on all fours ; then, something stronger would be required to support the downward pressure of the organs, than mere skin and muscles. Quite a forcible argument this, in favor of the naturally erect position of man.

Dr. B.—In brutes, the breast-bone is long and narrow, and the ribs extend far down upon the spine. They are often more numerous than in man. In the hyæna, there are 32 ; in the horse, 36 ; in the sloth, 46 ; while in man there are but 24. Their chest is compressed laterally, and is narrow and keel-shaped in front.

Emily.—This arrangement, by bringing the fore feet nearer each other, so that they stand perpendicularly under the trunk, will contribute to the firmness and facility with which this part of the body is supported.

Dr. B.—Passing over several other peculiarities in the structure of the pelvis and inferior extremities, let us look at the foot.

Emily.—Here must be some important peculiarities, for no animal in the world, that I know of, has a foot in the least resembling man's.

Dr. B.—The human foot, to which is finally transmitted the weight of the whole body, is larger, broader, stronger and more solid in proportion to the body, than that of any other creature. It is formed by numerous small bones, which being connected together by means of cartilages, are endowed with great firmness and elasticity. The general form of the foot is that of an arch resting on its two extremities, the heel and toes. No animal, besides man, rests the foot on the heel.

Emily.—But what great object is answered by this

difference in the structure of the foot? I really do not observe any as yet.

Dr. B.—Consider one moment, and you must see how beautifully this arrangement conduces to facility and security in walking. In setting down the foot in walking, the heel first touches the ground, but being a little in the rear of the leg, does not receive the direct weight of the body.

Emily.—And thereby prevents a painful jar, which would unavoidably take place, were the heel placed perpendicularly to the leg, or directly under instead of a little behind it.

Dr. B.—Excellent—you comprehend the tendency of these mechanical provisions, as if it were no new subject. But it is hardly possible that any one who has ever enjoyed that exhilarating exercise, dancing, should not be struck with that admirable mechanism which gives such grace and facility to the movements of the foot. The heel having now touched the ground, the weight of the body falling a little before, carries down the rest of the foot by a gradual and steady motion. The heel and toes now both touching the ground, some force is expended in spreading out and separating to their fullest extent, the pieces of this elastic arch.

The human heel, by its great size and backward projection, has the advantage of affording a large space for the attachment of the muscles, by which it is raised in progression. Where it rests on the ground, it is covered by nothing but skin and cellular tissue, whereas in the brutes, various muscles and tendons pass over the heel, in their course to the sole of the foot.

Emily.—This must effectually prevent them from walking like man, since the muscles would be compressed and prevented from action. But is it so in the apes also? The orang-utang, you know, is said to walk like man.

Dr. B.—They are taught to walk sometimes, but it is always with feeble and tottering steps. Their foot is

constructed like that of other brutes, and they are equally destitute of the other conditions of the erect stature.

The office of the lower limbs in the support and progression of the body, is also indicated by their superior length and strength. Their length is equal to that of the head and trunk together, and when compared with those of the orang-utang, the latter appear remarkably slim and feeble.

Emily.—I hope you are not going to pass over what is after all the most striking peculiarity in the human skeleton, the hand.

Dr. B.—That would be a sin of omission indeed, to forget that member which Aristotle emphatically denominates “the organ of all organs.” The Stagyrte has also said that man alone, has hands really deserving the name. This superiority arises chiefly from the size and strength of the thumbs, which, by being brought in opposition to the fingers, enables them to grasp spherical bodies, and take a firm hold on whatever they seize. It is indispensable in all the mechanical offices of life, which without it, could not be exercised at all. A French philosopher, struck with the superiority which the hand gives him over other animals, has written a book to prove, that man is the wisest of all animals, because he has hands.

Emily.—Wherein does the hand of man differ from that of the monkeys? They seem to handle objects with as much facility, and grasp them as firmly as man. True, they are not quite so well shaped and graceful.

Dr. B.—When closely examined, it will be found that these organs are far less perfect than man’s. In the first place, the thumb, which we said was the most distinguishing member of the human hand, is slender and weak; the other fingers are also slender and long. Secondly, they have no separate muscle to bend the thumb, as man has, but it is bent by the same muscle that bends the fingers.

Emily.—And for this reason they are incapable of those actions where the motion of the thumbs is combined with that of the fore and middle fingers, and thus debarred from performing those delicate operations that are required in works of human art.

Dr. B.—This finishes our account of the *passive* class of organs, engaged in locomotion.

Emily.—Next then we come to the *active* class, or the muscles, which operate on and set the former in motion. You said in our first conversation, that they are the masses of red-coloured flesh, which we see in the shoulder of mutton, and are composed of delicate fibres running parallel to one another and in the direction of the length of the muscle.

Dr. B.—I am glad your memory is so faithful; for the subjects we are considering, are so connected together, that if we forget one part, we lose a clue to all the rest. The middle portion of a muscle is always its largest part; then it goes on diminishing in size towards each extremity, when it terminates in what are called its tendons. These are of a white shining appearance, beautifully contrasting with the red fleshy mass of muscle, and are formed of exceedingly strong, but small fibres, very intimately connected together, by a sort of interlacing similar to what the sailors call *splicing*. They are thus made the most powerful texture in the whole body, and this joined with their little bulk, gives them every advantage, without compromising the beauty or convenience of the parts into which they are inserted.

Emily.—The body would indeed have been awkward and full of inequalities, had the muscles terminated in large, fleshy extremities.

Dr. B.—Now, several tendons may be inserted together in an extremely small space, without producing deformity or irregularity.

Emily.—But into what are the muscles inserted? Are they not free and unattached?

Dr. B.—Certainly not; how then could they have

acted on the bones? Every muscle is attached by its extremities, generally to the bones, though in a few instances one of the points of attachment may be a soft part. They are supplied with arteries, veins and nerves in greater abundance, than any other organs. The thumb receives more nerves, than is sent to the whole liver. They are fixed to the skeleton, lying in successive layers over one another, though slightly separated by cellular tissue, filling up the general outline of the body, and giving distinctness and character to its forms.

Emily.—Those are muscles swelling under the skin, in the motion of the arms or feet, are they not? I have often observed them very prominent in paintings and statues.

Dr. B.—More so probably, than you ever did in the human figure. It is an exaggeration which the Italian masters delighted in, and the moderns servilely copy it from them.

The muscles are the grand organs of locomotion, moving the body from place to place, and giving us power to execute the most delicate operations. This effect they produce by virtue of their contractile power, of which we have already spoken. The contraction of a muscle by shortening the distance between its two extremities, must of course approximate the parts to which they are attached.

Emily.—You observed just now, Dr. B., that the muscles are attached to the bones, and hence I cannot possibly conceive how this approximation can be effected. For if a muscle lie along on a bone through its whole length, with its extremities fixed in the extremities of the bones, how in the name of common sense, can these two ends of the bone be brought nearer together, without bending or breaking the bone.

Dr. B.—I perceive you have one very important fact yet to learn about the relative situation of the bones and muscles, for they are never inserted in the manner you supposed. Recollect that both extremities of the mus-

cle are not attached to the same bone, but to different bones. Of course, the approximation must be effected by the intervention of a joint, the bones turning upon each other as upon a hinge.

Emily.—Then the bones may represent so many levers; the parts with which they are connected, the weight to be raised; the muscle, the power which acts on the lever; and the joint will represent the fulcrum. Why, I had no idea before, that the movements of the body are produced by forces acting so strictly on mechanical principles. But levers, you know, are of several kinds; on which of these do the muscles act?

Dr. B.—All the three different kinds of levers are used in the body, but the most common, is that of the third kind.

Emily.—This is where the power is between the weight and the fulcrum. Why, this is the most disadvantageous of them all.

Dr. B.—That indeed; but though it requires a greater quantity of motion, yet this disadvantage is amply compensated for, by greater convenience,—in the construction of the body, every consideration has been sacrificed to convenience. As an instance of the manner in which motion is produced by muscular action, here is a figure of the bones of the arm with one of the muscles. Now you see how the muscle shortening



itself must inevitably bring the bones nearer together, or in other words, raise the arm.

Emily.—But only observe what a great loss of power there is, in consequence of the tendon being inserted so near the joint. How much easier the fore arm would be raised, if the muscles were inserted nearer the hand.

Dr. B.—And most certainly it would have been so, had the least possible expenditure of power been required; but what is the loss of this little power to Him who is the Source of all power? An advantage is gained by this arrangement which is absolutely necessary, and which could have been obtained in no other way—this disadvantageous use of power is repaid by greater velocity in the motion which it produces.

Emily.—True; I perceive now that had the tendon been inserted into the bone near the wrist, the hand would have been raised much more slowly.

Dr. B.—And of course it would have been rendered almost useless, since of all parts of the body, this requires great rapidity in its motions. Now, you see a very slight contraction of the muscle, (and the less it is, the quicker it is performed) is sufficient to raise the hand even up to the shoulder, though the part to which the muscle is attached is moved through a very short space.

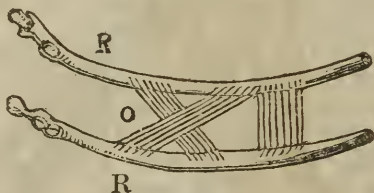
Emily.—Another objection to the muscle being inserted into the wrist has just struck me, which I did not observe before. When the fore arm is bent, the muscle would rise up at the bend of the arm, and destroy every thing like beauty or convenience.

Dr. B.—This shows forcibly, how in the mechanical construction of the body, every arrangement conduces to beauty, as well as utility. In every instance where there is a loss of muscular power, we may be sure that it is for some object which could have been obtained so well in no other way. It is strikingly exhibited where the loss of power arises from the obliquity of the muscles. For instance, two bones are required to be brought to-

wards each other by muscular power. If now, the muscle pass straight between them, this can be effected only to a short distance—say one third, the muscle shortening itself one third during its contraction.

Emily.—But if the muscle pass from one bone to the other obliquely, it may shorten itself no more, and yet bring them even twice as near. What a simple contrivance! but one which I never should have imagined.

Dr. B.—It is admirably witnessed in the ribs, which, during respiration, are constantly approaching and receding from each other. In the following figure, letters



R. R. represent the two ribs. If the fibres of the muscle by which they are to be approximated, run straight forward across perpendicular to the bones, they will move through only one third of the space between them, supposing the muscle shortens itself only one third during its contraction. But taking an oblique direction, as represented in O, they may contract but one third of their length, and bring the ribs together.

Another instance too, where beauty and utility are both obtained by a sacrifice of power, may be seen in the arrangement of the tendons that move the toes and fingers. Instead of passing in a straight line from the arm to the hand, which would have been exceedingly clumsy, they are bound down at the wrist by a fibrous band, under which they move with perfect ease, as you may see in this next cut. In this way, though greater force is required, yet greater velocity is obtained.

Emily.—And it is by arrangements of this kind, entirely mechanical in their nature, that the muscles exert their power, and produce those varied movements required in the locomotion of the body. The study of the animal system might give a lesson to the mechanic, as well as to the philosopher—the man of books.



Dr. B.—Not only are the movements of the body produced in this manner, but also the various attitudes which we assume, require the action of a certain series of muscles.

Emily.--That muscular action is necessary in running walking, &c. is obvious enough, but certainly

ly you do not mean to say that in standing still, or lying down, there is any exertion of muscular power?

Dr. B.—You think then, that the body is so constructed, that when placed on its feet, it will stand without support or exertion. Do you imagine that a lifeless body would stand on its feet without support?

Emily.—I acknowledge I am wrong, but still I do not perceive how this exertion is made, which keeps the body upright.

Dr. B.—It is true that the human body is constructed

for the erect position, and that its weight falls within the base of support, the feet, and therefore if formed of a single piece like a marble statue, would stand without the need of other assistance. But it is to be recollected that the body is composed of various pieces, connected together by joints that are easily bent by the superincumbent weight, and that consequently this tendency must be counteracted by suitable provisions. These provisions are found in the action of the muscles.

Emily.—How is this—the muscles bend the joints, and therefore the more strongly they act, the more difficult will it be for the body to keep erect.

Dr. B.—There are muscles, not only to bend the joints, but others whose office it is to bring the limbs back again to their unbent position. The former are called *flexors*, the latter *extensors*. Generally, the body when left without support of any kind, has a tendency to fall forward, and if we examine the connexions of some of its parts, we shall immediately see the cause.

Emily.—I recollect you mentioned that the head slightly preponderated forward, and this I suppose, assists in the general preponderance of the whole body in that direction.

Dr. B.—In standing therefore, the muscles on the back part of the neck are strongly exerted to maintain the head erect. The weight of the organs in the chest and abdomen, has a tendency to carry it forward, which is counteracted by the long and powerful muscles on the back. The whole weight of the trunk is now transmitted to the hip-joint which would be inevitably bent were it not prevented by muscular action; thence it is transmitted to the knee joint and finally to the ankle joint, both which are kept from bending by the same means. So that in standing there is a constant and wearisome exertion of the muscles to prevent the parts from bending on each other, and preserve the general equilibrium of the body.

Emily.—I might have known better, if I had but re-

membered how fatiguing it is, to continue standing still for any length of time—full as much, I verily believe, as to walk for the same space of time. But this cannot be the case with quadrupeds, for the standing posture seems to be one of rest to them. The horse after performing his task seldom lies down immediately, and all day he will stand in his stall without being fatigued.

Dr. B.—Because, his body resting on a wider base of support, the tendency to fall in any direction is obviously much lessened, and thus the equilibrium is preserved by a very little exertion of muscular power.

In some animals which are sometimes obliged to stand for a great length of time, we find curious contrivances for assisting the action of the muscles. Thus, the sea-birds, as the heron, which wade upon the shores of the sea and in the marshes for fish and reptiles, their natural food, had long excited the curiosity of naturalists, by the length of time in which they would stand motionless, expecting their prey. At last it was found, that in the lower extremity of the thigh-bone there is a deep cavity into which a corresponding projection in the leg can be shut at the pleasure of the animal. The thigh and leg being thus firmly locked together, and to all intents and purposes, constituting but one piece, no muscular power is necessary to keep them extended.

Emily.—I should think some mechanical contrivance was needed by all birds, to enable them to roost so long as they do without loosing their hold.

Dr. B.—And such a one is possessed by all birds, and is no less curious than that just described, which is possessed by only a few. The muscle which bends their talons, or draws them together so that they grasp an object, coming from the thigh, passes over the back part of the ancle-joint, or heel, proceeds along the foot, and is inserted into the toes.

Emily.—So that when the ancle-joint is bent, as it must be when the bird is perched, this muscle is bent at the same time, and the talons which obey the con-

traction of the muscle, are drawn closely and firmly around the object which they embrace. Is it not so?

Dr. B.—Yes; and observe too, that the greater the weight of the body by which the muscle is bent, the stronger will be the grasp. In this way they are enabled to grasp a branch so firmly, as to sleep secure, even when agitated by the winds.

Emily.—I have often wondered how birds could roost without being liable at every moment to lose their balance, and tumble off in their sleep. But how simply though perfectly is this accident obviated, by this singular arrangement. Still, some muscular exertion is necessary to prevent the body from pitching forward or backward, and I do not see how this can take place while the animal is sleeping.

Dr. B.—A certain degree of muscular strength indeed, they do exert; and it is so even with ourselves. When we lie down to sleep, the limbs must either be perfectly straight, which will require the action of the extensors, or bent, requiring the action of the flexors; so that whatever position we take, some muscles must be put into action. Birds are endowed with the power of making greater muscular exertion during sleep, and continuing it for a greater length of time, than man.

The most common kind of progression used by man, is that of *walking*, and though every body of sound limb is capable of performing this process, very few indeed are aware of the complicated, yet harmonious series of motions necessary to be executed before a single step can be completed.

Emily.—I can vouch for not making one of that few, for it would as soon have entered my head to ask how I eat or sleep, as how I walk. But I am no less desirous of being informed precisely how this process is accomplished.

Dr. B.—Suppose now a person to be standing firm and erect on both feet, ready to take the first step. His first motion is to throw the weight of the body on one

foot ; secondly, the hip, knee and ankle joints of the other limb are all a little bent—this shortens the limb and raises the heel ; thirdly, the thigh is still more bent on the hip—this carries the whole limb forward ; fourthly, the knee and ankle joints are straightened ; fifthly, the foot is brought to the ground, the heel touching first and then the toes. To effect the latter motion, the pelvis rolls upon the other thigh, which continues immoveable, carrying along with it that side of the body, in the same direction with the limb that is moved. Thus far no progression has been made, because the other part of the step, the bringing up the foot that is behind, is not completed. To do this—supposing the left limb is behind and the right in advance—the left side of the trunk is carried round towards the right and a little forward at the same time, by the right hip rolling on the right thigh—this motion throws the weight of the body on the right limb, which is firmly and completely extended, excepting the ankle joint ; secondly, the joints in the left limb, which is now perfectly straight and touching only at the toes, are all bent—this carries the limb forwards and brings it to the ground, in the same way as the former was.

Emily.—In this manner, the body does not advance in a straight line, but by a series of oblique lines running between two parallels from one to the other, producing a zig-zag course.

Dr. B.—And in order that these oblique movements may be equal to one another, so as not to carry the body out of the straight direction, our constant attention is required. Did you never observe how irregular a person's course is, when walking blind-folded ?

Emily.—I have seen persons attempt to walk from one end of a field to the other blind-folded, but with one or two exceptions, they were always brought up by the fence at the sides ; sometimes they even turned completely round, and came back to the very spot whence they started. It seems to be quite impossible with the

eyes blinded, to reach a spot at quite a short distance from the starting-point.

Dr. B.—In ascending an inclined plain, or a flight of steps, greater muscular exertion is required than in walking on a level, because when the foot first moved is brought to the ground, it is bent, instead of being straight; consequently, when the other foot is brought forward to the same level, the first limb must be straightened with the whole weight of the body resting upon it, in order that the body may be raised to the erect position.

Emily.—And it is this repeated exertion of raising the whole weight of the body on one leg, which produces the fatigue we soon feel in walking up a hill or a flight of steps, is it not? But the same fatigue is experienced in descending a hill, though perhaps not quite so soon; I do not exactly understand how this should be.

Dr. B.—Here, in bringing down the foot first moved to a level lower than the one on which the foot behind stands, the latter is obliged to sustain the whole weight of the body with the joints all bent, which, you know, requires considerable exertion.

Emily.—The peculiar difference then between ascending and descending an inclined plain, is, that in the former the limb is to be straightened with the whole weight of the body resting on it, and in the latter, it is to be bent, while sustaining the same weight. Am I not right?

Dr. B.—Yes, and quite a good distinction it is. In *leaping*, all the joints are put into a state of flexion, and then extended by a sudden and powerful motion. The force used in extending the limbs is so much greater than is necessary for overcoming the weight of the body, that it is carried from the ground, and, in consequence of the impulse received from the feet, in a forward direction. This sudden straightening is not confined to the limbs merely, but takes place in the back, and you can easily conceive how much this motion is assisted by the sudden extension of the spine, when you recollect that all the vertebrae are separated from one another by

a thick cartilage, possessing very great elasticity. In fishes, whose motions require a great elasticity, this cartilage is exceedingly thick. In the *great basking shark*, to increase this elasticity of the spine, there is in the centre of the cartilage, a cavity containing a small quantity of water. This is so strongly compressed, that in one instance when the cartilage was punctured, it was projected in a large stream four feet high.

Emily.—It is by this sudden and powerful extension of the body, I suppose, that salmon, trout, and other fishes are able to ascend waterfalls and other obstacles to their course, though many feet high.

Dr. B.—Yes, and this fact shows very forcibly the great elasticity of their spine.

Leaping is the method of progression used by animals whose anterior and posterior extremities are of disproportionate length. The hare, rabbit, jerboa, and squirrel, whose hind legs are so much longer than the others, as to unfit them from running, advance by a succession of leaps.

Emily.—What wonderful leaps a frog will take. Grasshoppers, whose legs are very long in proportion to their body, will make astonishing leaps for such little creatures. I have seen it calculated that the height to which a grasshopper leaps, is to the length of its body, as 200 to 1, and a flea, I believe, leaps still farther and with greater velocity.

Dr. B.—The leaping powers of the flea are wonderful, and have been thought worthy to be made the subject of a learned work by Roberval, entitled *de saltu pulicis*, or *leaping of the flea*.

Running seems to be a combination of both walking and leaping. It differs from the latter, for the reason that the feet do not move together, and from the former, because the foot behind is raised from the ground before the other has reached it; so that during every step, the body is suspended for a moment without any support.

Running, therefore, may be considered as a succession of short leaps with one foot. The leaps are made in rapid succession, and the toes only come to the ground. Such are a few of the principal methods of progression made use of by man; some others are seen in the inferior animals, but it is rather foreign to our purpose to describe them.

Of all the organs in the animal economy, the muscles are most under the control of habit,—habit even is necessary before the simplest and smallest efforts are easily performed. When we consider how difficult it is to perform almost any motion for the first time, it is truly astonishing to see how much may be finally accomplished by perseverance in a constant and regular habit.

Emily.—I am perfectly aware of this. I recollect when I contrasted the accuracy and rapidity with which the fingers of an accomplished player move over the keys of the piano, with my own awkward first attempts, I could not believe, what I am well convinced of now, that habit would in time make that perfectly easy, which appeared to me the result of a peculiar gift of nature.

Dr. B.—It is not only the muscles of the fingers, but those of every other part of the body over which habit has a wonderful influence. We have only to look into a circus, and see men dancing on slack ropes with as much ease apparently, as on an elastic floor, standing tip-toe on a horse's back, and while he is going at full speed, jumping through a hoop under which he passes and alighting upon his back on the other side, and many other feats equally astonishing, to be thoroughly convinced of this.

Emily.—In truth we may not go so far as that, for I understood that some wonderful things are done now-a-days at the gymnasias, not by men who make a business of it, but by staid and grave citizens, purely for pastime and exercise.

Dr. B.—Yes—Gymnasias are institutions now reviving in the world, for the purpose of developing that

muscular power, not one twentieth of which is called into use in the ordinary occupations of life. • It is quite astonishing to see how rapidly, and how much of this dormant power is awakened, by the various exercises of climbing, jumping, pulling, leaping, &c. which are performed at these places.

Emily.—But I really do not comprehend what great object is obtained after all, by having every muscle in the body carried to its maximum of developement. People are not going to get their living by climbing, or running for a wager, and if exercise be the only object in view, it appears to me, that sufficient for all necessary purposes, may be obtained with less trouble and in less time.

Dr. B.—Gymnastic exercises will not indeed give a man a livelihood, nor does any one suppose that they are absolutely necessary to keep him in existence, for many men enjoy excellent health and live to a good old age, without ever having entered a gymnasium. Behold the light in which these exercises are to be viewed in order to perceive their utility ;—the human constitution is continually subjected to the operation of a multitude of causes, the effects of which are, to weaken its powers, engender disease, and shorten its duration. It is impossible to avoid these causes for they exist in the air that we breathe, in the soil that we tread on, and the substances that we take into our bodies, and our only recourse is to make use of the means proper for withstanding their effects. The most obvious means—the only one which reason dictates, is to strengthen and develope to the utmost those very powers with which nature endowed our bodies, to enable them to resist the influence of the noxious agents by which they are encompassed. The body that is made strong and robust by habits of temperance and exercise, is the best adapted to withstand the effects of those exposures to which every person is more or less liable. This is the tendency of gymnastic exercises, and this is their utility.

Emily.—This is indeed a light in which I never viewed the matter before, and I humbly plead guilty to ill-grounded prejudice.

Dr. B.—To-morrow we shall speak of sleep, relations of the functions, and death.

CONVERSATION IX.

Sleep—necessary quantity varied by age, habit, temperament, &c.—state of the brain during sleep—dreaming, somnambulism—influence of sleep on the other functions—influence of habit on the animal and organic functions—difference in the origin of these functions—relations and mutual influence of the functions—laws of existence—death.

Emily.—To day you are to speak of sleep—that repose in which man participates with every other member of the animal kind. It is singular how necessary the periodical return of this state is to the animal system, inasmuch that to a person in good health, it is one of the most difficult things to keep awake twenty four hours in succession. I have heard the animal system aptly compared to a watch which required winding up once in twenty four hours—and this winding up is sleep.

Dr. B.—The comparison is hardly just, if by animal system you mean the constitution generally, for sleep is confined to what we have called the organs of animal life. The functions of organic life are not suspended in this way; respiration, circulation, secretion, &c. are in continual action. The organs of animal life require frequent intervals of repose, to recruit their exhausted powers, and in this state of inactivity, the individual seems to enjoy a mere vegetative existence.

Emily.—It has appeared to me a little surprising that

“nature’s sweet restorer,” though plunging the restless and active powers of the soul into a state resembling as nearly as we can conceive, that of annihilation, should yet be attended with a pleasure from which we part with reluctance.

Dr. B.—It seems to be a law of the animal economy that repose should be attended with pleasure, for the same reason that the gratification of our appetites is. The quantity of sleep required greatly varies according to age, temperament and habits. In early childhood, and in the second childhood of old age, where the small share of irritability is soon exhausted, and nature demands frequent repose, much of the time is spent in this state. It may be considered generally, that the quantity of sleep necessary to good health, gradually diminishes from birth till the age of mature manhood; from that period till death, its necessity as constantly increases. The young student knows how difficult it is for *him* to continue his application for a space of time which the veteran scholar will nearly double, without the least inconvenience. It is true, when ambition or some other powerful motive spurs him on, he may leave his bed early and burn his lamp late, but the unhappy effects that so often follow such exertions, show full well how unnatural they are.

In maturer life when the vital powers are not so soon exhausted, the system is capable of much greater exertions. Hear the declaration of Buffon, when speaking of those moments of abstraction and rapture which accompany the meditations of the great genius, and constitute his true hours of production and composition,—“I have spent fourteen or fifteen hours successively, at my desk, and still been in a state of pleasure.”

Emily.—I have heard too that Mr. ——— though now nearly seventy years old, generally spends fourteen hours every day in close study.

Dr. B.— The influence of habit also, in determining the necessary quantity of sleep, is considerable.

Some, from this cause, require eight or ten hours, while others are perfectly contented with half that quantity. The slight quantity of sleep that sometimes has been found to be sufficient, is almost incredible. The celebrated General Pichegru who commanded the armies of France during her revolution, declared to his physician, that in the course of his active campaigns, he had not for a whole year more than one hour's sleep, upon an average, in twenty four.

Emily.—It is hardly possible to conceive how one hour can afford the same refreshment which others find it difficult to obtain in six times that space.

Dr. B.—The refreshment produced by sleep does not seem to be in exact proportion to its duration. The first portion of sleep is undoubtedly most refreshing; it becomes less so the longer it is continued, and if carried too far is followed by effects of quite a contrary nature.

Emily.—The old proverb then, “one hour's sleep before mid-night is worth two after,” is founded in truth.

Dr. B.—Sleep is not a state of mere inaction, but one in which exhausted energies are recruited, and organic losses repaired. “The powers of the sensorium, seem to be wound up as it were, in the first periods of sleep; and a great part of the refreshment in later hours, seems more imputable to the simple repose of the organs, than to the recruiting powers peculiar to sleep.” Some people require after dinner, a nap of fifteen or twenty minutes, after which they can proceed to their business with fresh alacrity; whereas, a deprivation of their accustomed nap renders them drowsy and spiritless for the rest of the day. It is related of the European missionaries in China, that being obliged by their duties to take as little time as possible for that sleep in the middle of the day which is rendered necessary by the nature of the climate, they layed down with a brass ball in their hand, and under it a brass basin. The moment they dropped entirely asleep, the ball fell from their hand into

the basin and the noise waked them up, but the refreshment thus gained was found sufficient for their purpose.*

Emily.—And does not the refreshment procured by sleep depend considerably on the state of the mind? I have found sometimes when I have retired to rest with my mind deeply occupied with any subject, that my sleep is restless and disturbed by unpleasant dreams.

Dr. B.—Undoubtedly it does—sound, refreshing sleep requires that the mind should be free from care, anxiety and passion, and wearied in some degree by the employments of the day. The physical powers should also be fitted to repose by means of suitable exercise. Do you recollect that much-quoted passage in Shakspeare :—

“ I know ’tis not the sceptre and the ball,
The sword, the mace, the crown imperial,
The intertissued roba of gold and pearl,
The farsed title running fore the king,
The throne he sits on, nor the tide of pomp
That beats upon the high shore of the world;
No, not all these, thrice gorgeous ceremony,
Not all these, laid in bed majestically,
Can sleep so soundly as the wretched slave,
Who with a body filled and vacant mind
Gets him to rest, crammed with distressful bread,
————— who, from the rise to set,
Sweats in the eye of Phœbus, and all night
Sleeps in Elysium.”

HENRY V. *Act IV. Scene I.*

Emily.—Can sleep, Dr. B., be strictly considered as the repose of *all* the organs of animal life? You know we are frequently changing our position in sleep, which evidently indicates the exercise of the will, and consequently that part of the brain with which the will is connected. We likewise see and hear sometimes, and the intellectual faculties are frequently as active and acute as in our waking moments.

Dr. B.—Complete sleep, or the repose of *all* the

*T. Sully, the painter, one of his friends has informed me, gets his sleep in this way—using a key however instead of a ball.

organs of animal life, I know, is rarely enjoyed. Sleep is most commonly partial ; some portions of the nervous system are at rest, while others enjoy their wonted activity. I have already showed you how the sensorial power might be active, while the nervous, is in a state of repose. The exercise of the intellectual powers seems to be rather impaired or weakened, than entirely suspended, either in one or all. 'This is proved by the incoherence and irregularity of our ideas in sleep ; they float confusedly through the mind without continuity or distinctness, and like the changing figures of a phantasmagoria, are ever assuming another shape and name. The mind in its stupor grasps them feebly, and in attempting to compare them together, brings them into awkward and grotesque combinations.

Emily.—And yet you know that sometimes our ideas in sleep are quite original, and our reasonings remarkably logical.

Dr. B.—There are instances it is true, in which our sleeping thoughts seem to have a regularity, strength, and vividness unknown in our waking moments ; but probably we are the subjects of a little deception in this respect. When we call to mind, as we sometimes can, the jokes that “set the table in a roar” ; the argument that appeared irresistible ; and the verses, redolent with the odour of true genius, how stale, flat and insipid they appear.

The character of our dreams is frequently determined by the thoughts that have deeply engrossed the mind during the day. The ambitious man dreams of power and laurels ; the mathematician makes calculations ; the poet writes verses ; and the gourmand devours hecatombs of good things.

Emily.—There is a state of mind during sleep, called *somnambulism*, I believe, about which there are some curious facts—pray tell me what it actually is.

Dr. B.—It can hardly be called a state of sleeping or waking, though we are unable to explain all its phenom-

ena. Somnambulists, or sleep-walkers after sleeping soundly a short time get up from their bed, dress themselves, and go about their usual occupations. They have been known to converse, read, compose, &c. return to their bed, and wake in the morning utterly unconscious of what has happened. The mind seems to be in a state nearly akin to that known by the name of *revery*; the eye and ear remain open, but the impressions made on the mind are confused and indistinct, because the mind is here, as in common sleep, in a sort of stupor. For the same reason, though they have perfect command of the voluntary motions, yet they are just as likely to throw themselves from the window, and undertake divers perilous things, as to do any thing else. This is all we know of somnambulism.

Emily.—Does not sleep possess some influence over the organic functions? It seems hardly possible that they should go on with the same vigor, as when they are accompanied by the animal functions.

Dr. B.—They do not; the circulation is less frequent, respiration heavier, and digestion slow and difficult. All these phenomena strongly proclaim, how complete is the passive and even vegetable condition, during the periodical repose and renovation of nature.

Here ends our history of the functions of animal and organic life. You have seen how distinct they are in the animal economy, and yet how uniformly their mutual dependence is maintained.

Emily.—Yes—we seem to enjoy two lives, in a physiological sense; by one, we grow up and hold our existence; by the other, we operate on the external world and draw thenceforth the materials of happiness, or misery. By one, we constitute an independent, insulated being; by the other, we enter the grand chain of existence, a necessary and permanent link.

Dr. B.—The animal functions we have seen require intervals of repose; the organic functions, on the contrary, are incessantly going on—let respiration or circulation once cease, and existence is at an end.

We have seen also how differently the two lives are affected by habit. The very degree of perfection to which the animal life attains, depends chiefly on education; the organic is but very little under its control. By habit, we have seen that the motive powers are carried to their highest degree of energy and developement. It is the same too, with the sensations. By long continued training, the senses arrive to a state of acuteness unknown in the natural condition. The effect of sensation on the mind is also equally under the control of habit, though in a different way. By long continued repetition, the most vivid and poignant sensations, constantly grow weaker in their impressions, till at last, they are scarcely recognized by the mind. The most beautiful scenes of nature or art, after a time, pall upon the sight, and the most melodious sounds fall heavily on the ear. From the same cause too, sensations which are at first attended with pain or disgust, become in the end delightful sources of enjoyment.

Emily.—But by no means can we habituate the blood to move faster or slower through the vessels, or the respiratory organs to act quicker and more vigorously.

Dr. B.—In their origin also, the two lives differ. The organic, we find in full play and perfection at the moment of birth. The animal, on the contrary, is at this period, but imperfectly developed; weak, feeble, indistinct at first, time is required for its complete developement.

Another striking difference between the two lives, is not to be passed over—it regards the form and position of their organs. In the animal life, the organs are symmetrical; and are either in pairs, each being perfectly similar to the other, and placed on each side of the median line at equal distances from it, or single, placed directly over that line, and divided by it into two symmetrical halves.

Emily.—Let me interrupt you one moment to ask what you mean by the *median line*?

Dr. B.—It is an imaginary line passing through the middle of the body in a longitudinal direction, dividing it into two similar halves.

Emily.—And on this line are placed the nose, mouth, tongue, &c. and on each side of it are ranged the organs of vision, hearing, &c.

Dr. B.—The organs of organic life show none of this symmetry. They are irregular in their form, and situated without any regard to the median line. The stomach, liver, heart and spleen are placed in this manner, and their halves bear no resemblance to each other.

We have now gone through with the functions of animal existence ; we have examined them in the various classes of animals, and observed their points of resemblance and difference. As yet, however, we have not spoken particularly of their mutual relations, influence, and dependence, and the laws which regulate their combinations. As we have traced them separately and in detail from one class to another, we have seen them constantly undergoing some modification or other, and to one therefore who is but imperfectly acquainted with the subject, it would seem that by combining together all these modifications in an arbitrary manner, we could vary to infinity the structure of organic beings.

Emily.—Certainly ; we should only have to alter the condition of a single function, no matter how little, leaving all the rest unchanged, to have a specifically different being. For instance, if we change the structure of the digestive organs, we have a different animal, whether we alter those of respiration, circulation, sensibility, &c. or not.

Dr. B.—But such combinations as these which at first sight appear possible, do not exist in nature. For it must be recollected that each organ has not only its peculiar function to perform in the animal economy, but that it contributes with all the rest to the production of a common object. Now, this is effected not by joining their results together and making a sum total, but by

their mutual and necessary influence, which requires between them a certain correspondence of condition and harmony of action. The condition of one function will determine to a certain extent the condition of all the rest, because each requires the aid of all the rest in the performance of its destined office.

Emily.—We cannot then change the condition of the digestive organs, without making correspondent alterations in all the other organs. I see now very clearly that organization will not admit of that immense variety of forms, of which it at first sight seemed capable.

Dr. B.—Respiration, for instance, necessarily requires the circulation of the blood, and this must not be too quick nor too slow, but in direct accordance with the condition of the respiratory organs. The circulation is maintained by the action of the heart and blood-vessels—

Emily.—And these require the aid of the nervous power which is the cause of their motions, and the nervous system depends for its activity on the circulation and respiration. I do not see but this influence revolves in a circle—it is impossible to find a beginning or end.

Dr. B.—I need not mention to you how necessary—how indispensable in fact—is this correspondence and harmony of condition to the existence of a living being, and how completely any general result would be frustrated, by an arbitrary and heterogeneous assemblage of functions.

Emily.—It requires truly, no uncommon penetration to see how useless would be the power of sensibility for instance, were it not aided constantly by the muscular power. What would be the advantage of the sense of touch, could we not turn our hands towards palpable objects? of seeing, if we could not turn the head or eyes in every direction? Of what avail would be a great degree of activity in the respiratory organs, if the circulation were feeble? of strong and active powers of digestion, if the possessor were unprovided with means for taking its proper food? What would be the utility of

high intellectual endowments, if their exercise were rendered null and void by other incompatible conditions.

Dr. B.—It is on this mutual dependence of the functions and the aid they reciprocally give and receive, that are founded the laws which regulate the combinations of organs in the animal economy—laws, says Cuvier, “which have their origin in a necessity equal to that of mathematical or metaphysical laws.” For if the condition of one organ or set of organs be modified in a manner incompatible with a corresponding modification in the other organs, it is very evident that being could not exist. If we take one of the functions separately, and assuming it as a standard of comparison, observe the relations of the others with it, we shall see a little more distinctly how they are all made to conform to it.

Emily.—But you do not mean certainly that any one can regulate the conditions of the others, because the influence would then have a beginning and an end.

Dr. B.—Very true, but what I have said is not incompatible with the idea, that the conditions of the organs instead of being regulated by a particular one, are governed by each other.

Emily.—Well, then, to begin your comparison—which organ shall you take for the common standard? Suppose they are the organs of respiration.

Dr. B.—It is almost immaterial which we take, but as respiration is a function of the first importance, it will answer our purpose as well as any other. In the first place then let us see its relations with circulation. In the higher animals where respiration is performed by lungs, the circulation is provided with a double heart by which the blood is impelled to the body and lungs. Of the three classes of animals in which this kind of respiration exists, the Birds possess it in the greatest quantity and activity. Their inspirations are made more frequently, and their organs have greater extent comparatively, than in the mammiferous animals. The circulation has a correspondent degree of activity; in no other animals

are the pulsations of the heart so rapid and so frequently repeated. In Reptiles, we have seen that respiration is quite inactive and feeble, and they can dispense with it for a great length of time. See how perfectly in accordance with this condition is their circulation.

Emily.—The pulsations of the heart are quite slow and unfrequent, and only half of the blood sent to the lungs requires its action, for the other half has just returned thence, and needs no change.

Dr. B.—In Fishes, respiration is performed by gills which separate the air from the water, and owing to this disadvantage, greater activity of both the respiration and circulation, is necessary to produce a given result.

In Insects, the air enters the body by numerous pores, not by a particular set of organs; of course neither heart nor blood-vessels are required to transmit the blood to these organs.

The relations between respiration and muscular motion are exceedingly obvious and well defined. The quantity and activity of one are generally proportional to the quantity and activity of the other, for one of the principal uses of respiration, is to reanimate the muscular power.

Emily.—And is not this the reason why the respiration is always accelerated when we are taking exercise, or performing any task which requires considerable exertion of muscular power. Observe too, how a dog or horse pants, after running violently, or for any length of time.

Dr. B.—This is the reason, undoubtedly. In the birds and mammiferous animals which have the function of respiration developed to its highest degree of excellence, the muscular power is capable of the greatest and longest-continued exertions. Birds, in which we just observed that the respiratory function existed in its greatest perfection, are almost always in the air, and the locomotive feats which they sometimes perform are almost incredible.

Emily.—Such constant exertions must necessarily be attended by a great expenditure of power, and therefore a corresponding activity of those organs, whose function it is to purify and renovate the fluid from which it is supplied, is also required.

Dr. B.—In reptiles also, we find a condition of the muscular powers in perfect keeping with their feeble and inactive respiration. Their motions are slow and unfrequent, and there is a constitutional sluggishness and indolence. For several months in every year, they shut themselves up in holes and dark places, and remain in a state of torpidity, in which motion and sense are utterly suspended.

In fishes, there are relations between the quantity of respiration and that of muscular motion, no less uniform and striking. They consume but little air, and they have but little muscular power.

Emily.—I thought that they were remarkable in this respect. Their motions are certainly very rapid; and salmon are said to ascend falls thirty feet high.

Dr. B.—True, indeed, and the darting of a salmon or trout in the water is often compared to an arrow, but such rapid motions cannot be continued longer than a few minutes. Their powers are soon expended, and not receiving a proportional supply from the respiratory organs, their exertions are necessarily short.

The relations between the respiratory function and the nervous system, are just as strict and invariable. In cold-blooded animals, whose respiration is almost an accessory circumstance merely, the external senses are deficient in acuteness, and the mental faculties are limited and dull. The nervous system derives its energy from the blood, and it will always be proportional to the degree of renovation which this fluid receives from the action of the respiratory organs. In the reptiles, the nervous energy, weak as it is, is sufficient for their purpose. Strong sensations, and acute sensibility were not wanted by animals whose muscular power needs but little reanimation, because little is expended.

In birds, the nervous system bears as great a proportion to the bulk of the body, compared with other animals, as the respiratory organs. Hence, the acuteness of their sensations and their general superiority in mental activity strongly contrasts with the sluggishness of reptiles and the intellectual stupidity of fishes.

Digestion has also intimate relations with respiration.

Emily.—This is very obvious; for one great use of respiration is, to separate those portions of the food received into the blood, which are unfit for the purposes of the animal economy, as well as to expose to the renovating influence of the air, the really nutritive materials. It is the office of digestion also, to prepare the materials which are to supply the places of others that are taken away, and carried out from the system by means of the respiratory organs. There must of necessity, therefore, be a uniform proportion of energy between respiration and digestion.

Dr. B.—This is the reason why birds possess such strong powers of digestion, and require food at frequent intervals. In reptiles, on the contrary, the digestive powers are limited, and entire abstinence is easily borne for very protracted periods. In their torpid state, they lie for months without the slightest morsel of food.

Emily.—And the reason is very obvious; nothing is carried away from the system by respiration since this function is hardly perceptible, and consequently nothing is required from the digestive process.

Dr. B.—There is a very close relation between digestion, and sensation and motion. In the inferior animals, the principal purpose of the latter, is to assist in the performance of the former; both are constructed with a direct reference to the nature of the food. The carnivorous animal must not only have a set of digestive organs fitted to act upon raw flesh, but his senses must be sufficiently acute to distinguish his prey at a distance; his muscular power must be sufficient to enable him to pursue and overcome it; his claws must be sharp and

strong, in order that he may seize it and tear it in pieces ; and his teeth must be long, sharp and pointed, for the purpose of cutting and dividing it.

Emily.—And he must also possess the requisite courage and address to circumvent and attack his victim, otherwise all these advantages you have mentioned, will be of no avail to him.

Dr. B.—Certainly ; without these qualities, the lion and tiger would never dare to attack animals larger than themselves, and consequently could not exist.

Emily.—Without the requisite courage to encounter the thick-set snares of the poultry-yard, and the cunning and subtlety necessary to avoid them, Reynard would often go to bed supperless, and dream of, instead of feasting on chanticleer and his mates.

Dr. B.—Herbivorous animals, on the contrary, which can digest only vegetable food, have velocity of the muscular power instead of strength, whereby they avoid their enemies ; their feet are destitute of claws ; their teeth are blunt ; and their moral powers are characterised by timidity and distrust.

The laws which thus determine the relations between the different functions, are equally perceptible in fixing the relations between the different parts of the same system. In the digestive system, for instance, the construction of the jaws, the form of the teeth, the length, convolutions, and dilatations of the alimentary canal, are all determined by one another, and these relations are so constant and necessary, that, like the conditions of a mathematical problem, one being known, the rest are quickly inferred.

Emily.—These laws of existence do indeed form a necessary condition of the existence of organic beings. I never was before aware that laws presided over their formation, as uniformly as attraction and repulsion over the operations of inorganic matter.

Dr. B.—Instead too of fettering the operations of nature, as might perhaps at first sight seem, and prescribing

limits to its power, it is but another signal instance of that beautiful harmony which pervades all its works, and binds them together as necessary parts of the great general system. It has been owing to an ignorance of these beautiful and invariable laws of organization, that so many impositions have been practised on the community, and even deceived men of good common sense, and in other matters, of general intelligence. Those abominable monstrosities so often exhibited about as veritable specimens of the *mermaid* race, are violations of nature as gross and absurd as the Centaur of the ancients, or the poetical image which embellishes the Kentucky hunters' song, "half horse, half alligator."

To recapitulate these remarks, we observe generally that the grand result produced by the action of the vital organs, is not to be considered merely as a combination of the action of each particular organ, but as the effects of their necessary and mutual relations; and consequently that a change in the condition of one function will not only vary the general result, but also the particular action of the other functions.

Emily.—It seems in fact to be very like the economy of our own republic, where each portion of which it is composed, not only regulates its own concerns, but contributes its part to the management of the common interest.

Dr. B.—Your comparison is as just as it is clear. Had a knowledge of these principles been more generally extended, the world would have been spared those absurd theories, which under the name of philosophy, have been seriously constructed and greatly admired. One of these philosophers imagines that man owes his superiority over the animal creation, to the form of his hands; another, to his erect position; and many others to his intellectual gifts, and have proved the truth of their theories, by showing what a different creature man would be without these several conditions.

Emily.—To talk about what man would be, with a different conformation of this or that organ, is about as

absurd as it would be for a geometer to speculate on the probable state of geometry, if the three angles of a triangle amounted to only one, instead of two right angles.

Dr. B.—Man is what he is, not because he possesses this organ or that, but because he is the general result or product of a certain system of organization.

Such is the history of organic beings ; it only remains for us now, to behold their natural termination in death. The animal functions first feel the approach of the “grim destroyer,” and are one after another gradually extinguished before the organic are sensibly affected. The muscles lose the power of action, till the limbs and trunk are motionless. The senses lose their acuteness ; vision grows dim and the eye-lids close ; the ear is insensible to sound ; the voice is weak and husky. The intellectual faculties soon participate in the decay of the senses. The memory is obliterated ; judgment errs ; and the consciousness of the world without fades from the mind. Respiration, circulation, and the other organic functions still continue, till death finally seizes upon them. Respiration is slackened ; the motions of the heart are feeble and irregular ; the blood retires from the vessels of the skin to the central organs, where it stagnates and dies. Thus proceeding from the circumference to the centre, life is gradually extinguished throughout all the system. The body is now subjected to the ordinary laws of matter ; putrefaction and decomposition commence ; and this admirable machine, which but a moment before, as it were, was charged with youth, beauty and intelligence, is scattered to the elements.





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